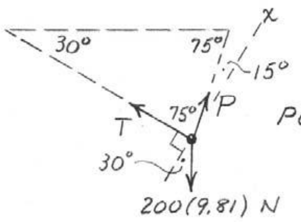
3/1

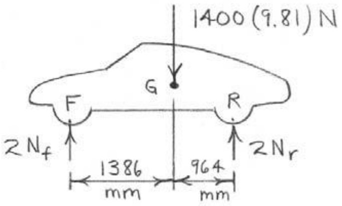


$\Sigma F_x = 0$

$P\cos 15° - 200(9.81)\cos 30° = 0$

$\underline{P = 1759\ \text{N}}$

3/2



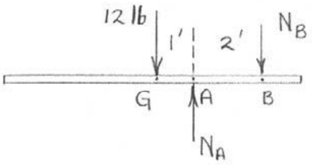
$+\uparrow \Sigma F = 0: \quad 2N_f + 2N_r - 1400(9.81) = 0$

$\circlearrowleft\!+ \Sigma M_F = 0: \quad -1400(9.81)(1386) + 2N_r(1386 + 964) = 0$

Solution : $\begin{cases} N_f = 2820\ \text{N} \\ N_r = 4050\ \text{N} \end{cases}$

Assumes G midway between left and right wheels.

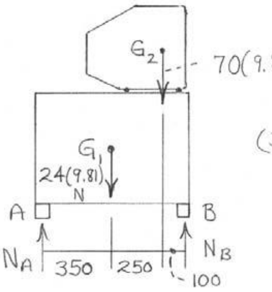
3/3



$\circlearrowleft\!+ \Sigma M_B = 0: \quad 12(3) - N_A(2) = 0$

$\underline{N_A = 18\ \text{lb}}$

3/4



(Dim. in mm)

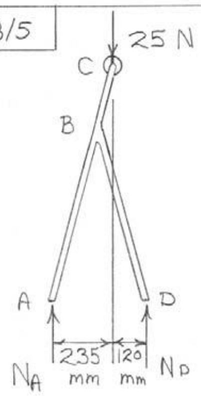
$\circlearrowleft\!+ \Sigma M_A = 0: \quad -24(9.81)350 - 70(9.81)(600) + N_B(700) = 0$

$\underline{N_B = 706\ \text{N}}$

$+\uparrow \Sigma F = 0: \quad N_A + 706 - (70 + 24)(9.81) = 0$

$\underline{N_A = 216\ \text{N}}$

3/5



$\circlearrowleft \Sigma M_A = 0:$

$N_D(355) - 25(235) = 0$

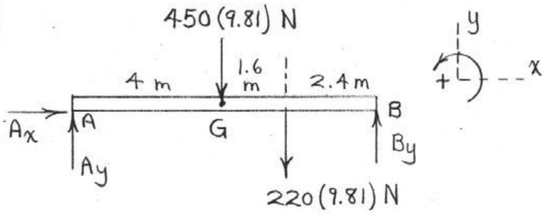
$\underline{N_D = 16.55\ \text{N}}$

$+\uparrow \Sigma F = 0:$

$N_A + 16.55 - 25 = 0$

$\underline{N_A = 8.45\ \text{N}}$

3/6



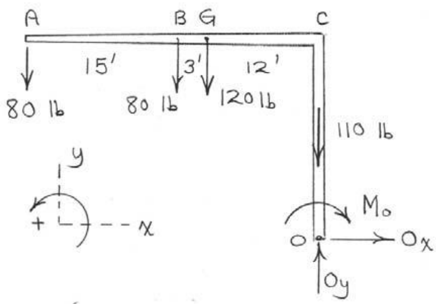
From $\Sigma F_x = 0$, $A_x = 0$

$\Sigma M_A = 0: \quad -450(9.81)4 - 220(9.81)(5.6) + B_y(8) = 0, \quad \underline{B_y = 3720\ \text{N}}$

$\Sigma F_y = 0: \quad A_y - 450(9.81) - 220(9.81) + 3720 = 0$

$\underline{A_y = 2850\ \text{N}}$

3/7



$\Sigma F_x = 0: \quad \underline{O_x = 0}$

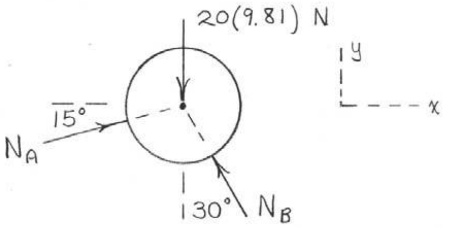
$\Sigma F_y = 0: \quad O_y - 80 - 80 - 120 - 110 = 0$

$\underline{O_y = 390\ \text{lb}}$

$\Sigma M_O = 0: \quad 80(30) + 80(15) + 120(12) - M_O = 0$

$\underline{M_O = 5040\ \text{lb-ft CW}}$

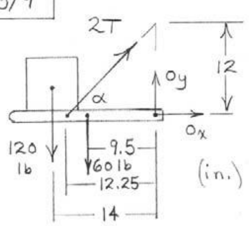
3/8



$$\begin{cases} \Sigma F_x = 0: & N_A \cos 15° - N_B \sin 30° = 0 \quad (1) \\ \Sigma F_y = 0 & N_A \sin 15° + N_B \cos 30° - 20(9.81) = 0 \quad (2) \end{cases}$$

Solution : $\begin{cases} N_A = 101.6 \text{ N} \\ N_B = 196.2 \text{ N} \end{cases}$

3/9

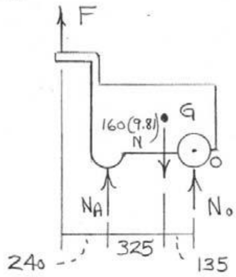


$\alpha = \tan^{-1} \frac{12}{12.25} = 44.4°$

$\curvearrowleft + \Sigma M_O = 0: \quad 120(14) + 60(9.5) - 2T \sin 44.4° (12.25) = 0$

$\underline{T = 131.2 \text{ lb}}$

3/10



With $F = 0$:

$\curvearrowleft + \Sigma M_O = 0: \quad 160(9.81)(135) - N_A(460) = 0$

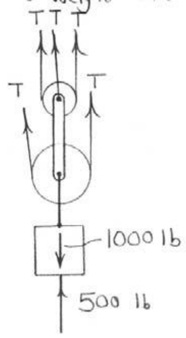
$N_A = 461 \text{ N}$

For $\frac{1}{2} N_A$:

$\curvearrowleft \Sigma M_O = 0: \quad 160(9.81)(135) - \frac{461}{2}(460) - F(700) = 0$

$\underline{F = 151.4 \text{ N}}$

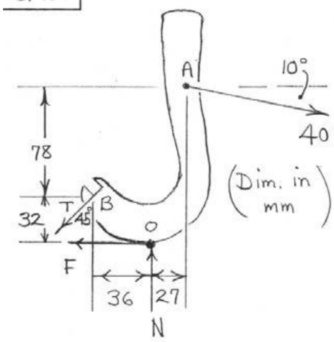
3/11 FBD of 1000-lb weight and lower pair of pulleys:



$\uparrow \Sigma F = 0: \quad 5T + 500 - 1000 = 0, \quad \underline{T = 100 \text{ lb}}$

(We assume that the nonverticality of some of the cables is negligible.)

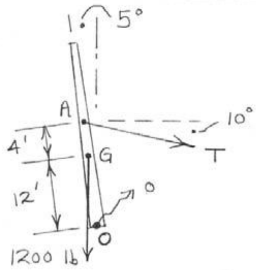
3/12



$\curvearrowleft + \Sigma M_O = 0: \quad -40 \cos 10° (110) - 40 \sin 10° (27) + T \cos 45° (32) + T \sin 45° (36) = 0$

$\underline{T = 94.0 \text{ N}}$

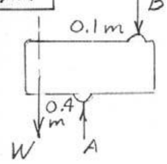
3/13



$\curvearrowleft + \Sigma M_O = 0: \quad 1200(12 \sin 5°) - T \cos 15° (16) = 0$

$\underline{T = 81.2 \text{ lb}}$

3/14



$W = 300(9.81) = 2943 \text{ N}$

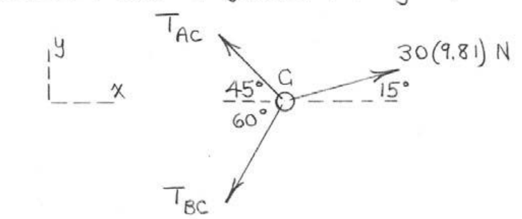
$\Sigma M_A = 0; \quad 2943(0.4) - B(0.6) = 0$

$\underline{B = 1962 \text{ N}}$ or $\underline{1.962 \text{ kN}}$

$\Sigma F = 0; \quad A = 2943 + 1962$

$\underline{= 4910 \text{ N}}$ or $\underline{4.91 \text{ kN}}$

3/15 FBD of junction ring C:

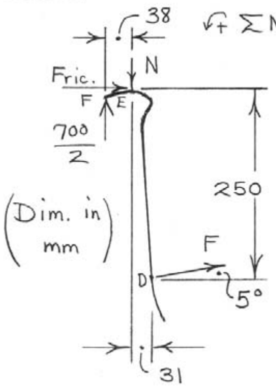


$$\begin{cases} \Sigma F_x = 0: -T_{AC}\cos 45° - T_{BC}\cos 60° + 30(9.81)\cos 15° = 0 \\ \Sigma F_y = 0: T_{AC}\sin 45° - T_{BC}\sin 60° + 30(9.81)\sin 15° = 0 \end{cases}$$

Solve simultaneously to obtain

$$\begin{cases} T_{AC} = 215 \text{ N} \\ T_{BC} = 264 \text{ N} \end{cases}$$

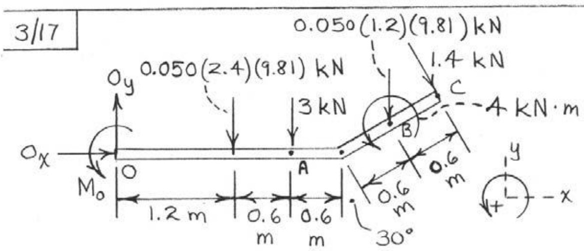
3/16 Consider the right prybar:



$\curvearrowleft + \Sigma M_E = 0: -\frac{700}{2}(38) + F\cos 5°(250) + F\sin 5°(31) = 0$

$\underline{F = 52.8 \text{ N}}$

3/17



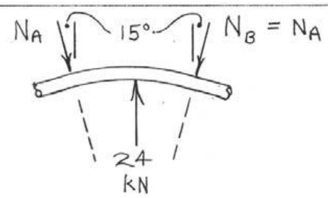
$\Sigma F_x = 0: \quad O_x + 1.4\sin 30° = 0$

$\underline{O_x = -0.7 \text{ kN}}$

$\Sigma F_y = 0: \quad O_y - 0.050(2.4)(9.81) - 3 - 1.4\cos 30° - 0.050(1.2)(9.81) = 0, \quad \underline{O_y = 5.98 \text{ kN}}$

$\Sigma M_O = 0: \; M_O - 0.050(2.4)(9.81)(1.2) - 3(1.8) - 0.050(1.2)(9.81)(2.4 + 0.6\cos 30°) + 4 - 1.4(2.4\cos 30° + 1.2) = 0, \quad \underline{M_O = 9.12 \text{ kN·m}}$

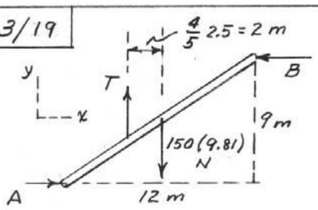
3/18



$\uparrow \Sigma F = 0: \quad 24 - 2N_A\cos 15° = 0$

$\underline{N_A = N_B = 12.42 \text{ kN}}$

3/19



$\Sigma F_y = 0; \quad T - 150(9.81) = 0$

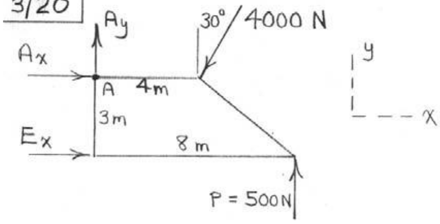
$T = 1472 \text{ N}$

$\Sigma F_x = 0; \quad A = B$

$\Sigma M = 0; \quad 1472(2) - A(9) = 0$

$\underline{A = B = 327 \text{ N}}$

3/20



$\Sigma F_x = 0: \; A_x + E_x - 4000\sin 30° = 0$

$\Sigma F_y = 0: \; A_y - 4000\cos 30° + 500 = 0$

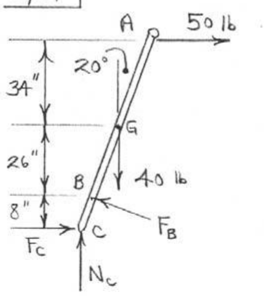
$\Sigma M_A = 0: \; E_x(3) + 500(8) - 4000\cos 30°(4) = 0$

$\Rightarrow \underline{A_x = -1290 \text{ N}}, \; \underline{A_y = 2960 \text{ N}}, \; \underline{E_x = 3290 \text{ N}}$

For maximum P: $E_x = 0$ and $\Sigma M_A = 0$:

$P(8) - 4000\cos 30°(4) = 0, \quad \underline{P = 1732 \text{ N}}$

3/21



(a) Including 40-lb Weight:

$$\circlearrowleft\!+\ \Sigma M_C = 0:\quad 50(68) + 40\,(34\tan 20^\circ) - F_B\,\frac{8}{\cos 20^\circ} = 0$$

$$F_B = 458 \text{ lb}$$

$$\xrightarrow{+}\ \Sigma F = 0:\quad F_C - 458\cos 20^\circ + 50 = 0$$

$$\underline{F_C = 380 \text{ lb}}$$

(b) Exclude 40-lb weight;

$$\circlearrowleft\!+\ \Sigma M_C = 0;\quad 50(68) - F_B\,\frac{8}{\cos 20^\circ} = 0$$

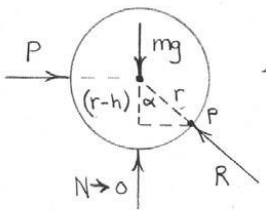
$$F_B = 399 \text{ lb}$$

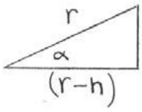
$$\xrightarrow{+}\ \Sigma F = 0:\quad F_C - 399\cos 20^\circ + 50 = 0$$

$$\underline{F_C = 325 \text{ lb}}$$

3/22

$$\cos\alpha = \frac{r-h}{r}$$





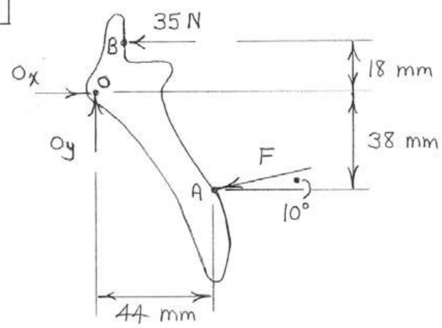
$$\sqrt{r^2-(r-h)^2} = \sqrt{2rh-h^2}$$

$$\sin\alpha = \sqrt{2rh-h^2}\,/\,r$$

$$\circlearrowleft\!+\ \Sigma M_P = 0:\quad P(r-h) - mg\,r\sin\alpha = 0$$

$$\Rightarrow\ \underline{P = \frac{mg\sqrt{2rh-h^2}}{r-h}}$$

3/23



$$\circlearrowleft\!+\ \Sigma M_O = 0:\quad 35(18) - (F\cos 10^\circ)(38) - (F\sin 10^\circ)(44) = 0$$

$$\underline{F = 13.98 \text{ N}}$$

$$\Sigma F_x = 0:\quad O_x - 35 - 13.98\cos 10^\circ = 0$$

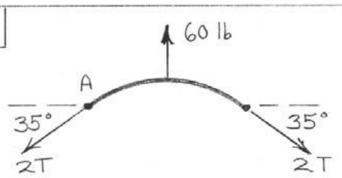
$$O_x = 48.8 \text{ N}$$

$$\Sigma F_y = 0:\quad O_y - 13.98\sin 10^\circ = 0$$

$$O_y = 2.43 \text{ N}$$

$$O = \sqrt{48.8^2 + 2.43^2} = \underline{48.8 \text{ N}}$$

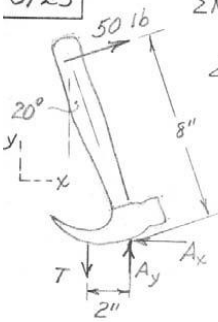
3/24



$$+\!\uparrow \Sigma F = 0:\quad 60 - 4T\sin 35^\circ = 0$$

$$\underline{T = 26.2 \text{ lb}}$$

3/25



$\Sigma M_A = 0;\ 50(8) - 2T = 0,\ \underline{T = 200 \text{ lb}}$

$\Sigma F_x = 0;\ 50\cos 20^\circ - A_x = 0$

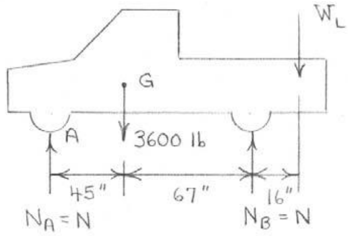
$A_x = 46.98 \text{ lb}$

$\Sigma F_y = 0;\ A_y + 50\sin 20^\circ - 200 = 0$

$A_y = 182.9 \text{ lb}$

$A = \sqrt{(46.98)^2 + (182.9)^2} = \underline{188.8 \text{ lb}}$

3/26



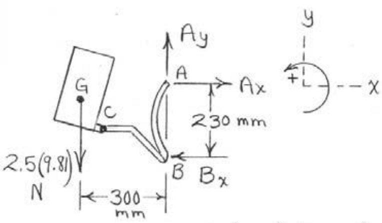
$$\circlearrowleft\!+\ \Sigma M_A = 0:\quad 3600(45) - N(112) + W_L(128) = 0$$

$$+\!\uparrow \Sigma F = 0:\quad 2N - 3600 - W_L = 0$$

Solve to obtain $N = 2075$ lb

$\underline{W_L = 550 \text{ lb}}$

3/27 Entire unit:



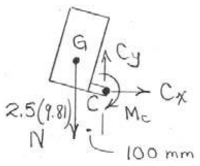
$\Sigma M_A = 0: \ 2.5(9.81)(300) - B_x(230) = 0$

$\underline{B_x = 32.0 \text{ N}}$

$\Sigma F_x = 0: \ A_x - 32.0 = 0, \quad \underline{A_x = 32.0 \text{ N}}$

$\Sigma F_y = 0: \ A_y - 2.5(9.81) = 0, \quad \underline{A_y = 24.5 \text{ N}}$

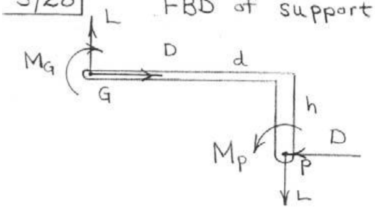
Fixture only:



$\Sigma M_C = 0: \ 2.5(9.81)(100) - M_C = 0$

$\underline{M_C = 2.45 \text{ N·m CW}}$

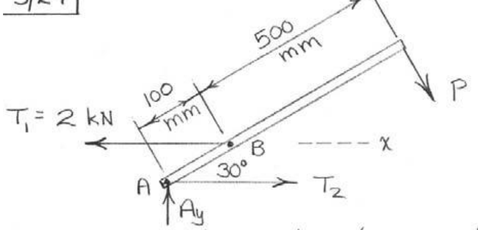
3/28 FBD of support & model:



$\Sigma M_P = 0: \ M_P - M_G - Ld - Dh = 0$

$\underline{M_G = M_P - Ld - Dh}$

3/29



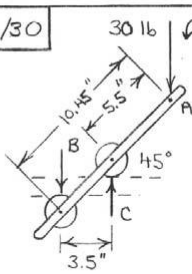
$\Sigma M_A = 0: \ P(500 + 100) - 2(100 \sin 30°) = 0$

$P = 0.1667 \text{ kN} \quad \text{or} \quad \underline{P = 166.7 \text{ N}}$

$\Sigma F_x = 0: \ 0.1667 \sin 30° + T_2 - 2 = 0$

$\underline{T_2 = 1.917 \text{ kN}}$

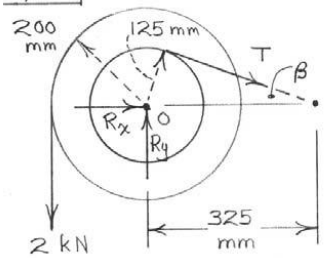
3/30



$\Sigma M_C = 0: \ B(3.5) - (30 \cos 45°)(5.5) = 0, \quad \underline{B = 33.3 \text{ lb}}$

$\Sigma M_B = 0: \ C(3.5) - (30 \cos 45°)(10.45) = 0, \quad \underline{C = 63.3 \text{ lb}}$

3/31



$\begin{cases} \sin\beta = \frac{125}{325} = \frac{5}{13} \\ \cos\beta = \frac{12}{13} \end{cases}$

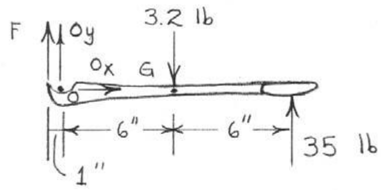
$\Sigma M_O = 0: \ 2(200) - T(125) = 0, \quad T = 3.2 \text{ kN}$

$\Sigma F_x = 0: \ 3.2\left(\frac{12}{13}\right) + R_x = 0, \quad R_x = -2.95 \text{ kN}$

$\Sigma F_y = 0: \ R_y - 2 - 3.2\left(\frac{5}{13}\right) = 0, \quad R_y = 3.23 \text{ kN}$

$R = \sqrt{R_x^2 + R_y^2} = \sqrt{2.95^2 + 3.23^2} = \underline{4.38 \text{ kN}}$

3/32

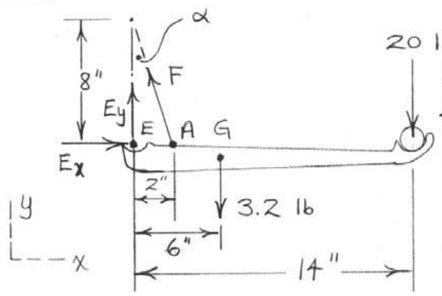


$\Sigma M_O = 0: \ -F(1) - 3.2(6) + 35(12) = 0$

$\underline{F = 401 \text{ lb}}$

3/33

$\alpha = \tan^{-1}\frac{2}{8} = 14.04°$



Assume that A & E are on a horizontal line

$\Sigma M_E = 0: \ F\cos 14.04°(2) - 3.2(6) - 20(14) = 0$

$\underline{F = 154.2 \text{ lb}}$

$\Sigma F_x = 0: \ -154.2(\sin 14.04°) + E_x = 0$

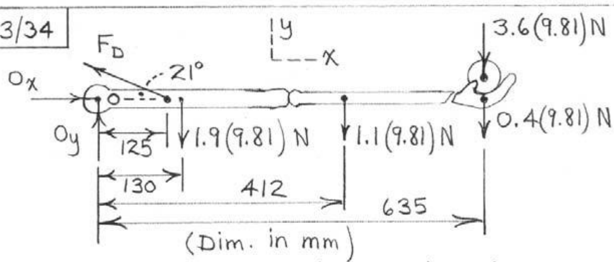
$E_x = 37.4 \text{ lb}$

$\Sigma F_y = 0: \ 154.2 \cos 14.04° - 3.2 - 20 + E_y = 0$

$E_y = -126.4 \text{ lb}$

$E = \sqrt{E_x^2 + E_y^2} = \sqrt{37.4^2 + 126.4^2} = \underline{131.8 \text{ lb}}$

3/34

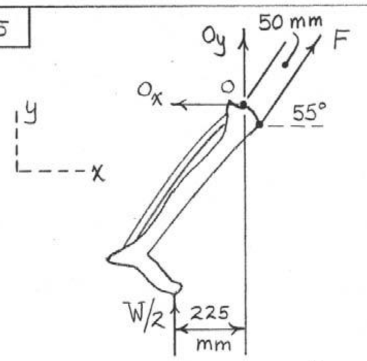


$\circlearrowleft + \Sigma M_O = 0: \; F_D \sin 21°(125) - 1.9(9.81)(130)$
$- 1.1(9.81)(412) - (3.6+0.4)(9.81)(635) = 0$
$\underline{F_D = 710 \text{ N}}$

$\xrightarrow{+} \Sigma F_x = 0: \; O_x - 710 \cos 21° = 0, \quad \underline{O_x = 662 \text{ N}}$

$+\uparrow \Sigma F_y = 0: \; O_y + 710 \sin 21° - (1.9 + 1.1 + 3.6 + 0.4)\,9.81$
$= 0, \quad \underline{O_y = -185.6 \text{ N}}$

3/35



$\circlearrowleft + \Sigma M_O = 0: \; F(50) - \frac{W}{2}(225) = 0, \quad \underline{F = 2.25W}$

$\Sigma F_x = 0: \; -O_x + 2.25W \cos 55° = 0, \quad O_x = 1.291W$

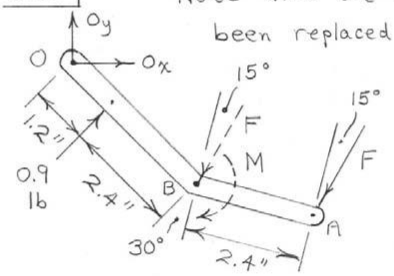
$\Sigma F_y = 0: \; \frac{W}{2} + O_y + 2.25W \sin 55° = 0$

$O_y = -2.34W$

$O = \sqrt{O_x^2 + O_y^2} = \sqrt{(1.291W)^2 + (2.34W)^2} = \underline{2.67W}$

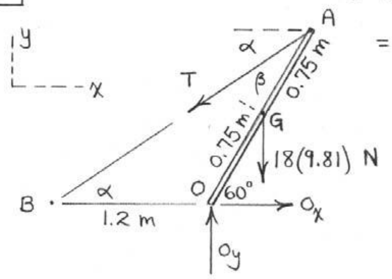
3/36

Note that the force F has been replaced by a force-couple system at B (dashed), where $M = F(2.4 \cos 15°)$



$\circlearrowleft \Sigma M_O = 0: \; 0.9(1.2) - F(2.4 \cos 15°)$
$- F(3.6 \cos 15°) = 0$
$\underline{F = 0.1863 \text{ lb}}$

3/37



$\alpha = \tan^{-1}\left[\frac{1.5 \sin 60°}{1.5 \cos 60° + 1.2}\right]$
$= 33.7°$

$\beta = 90° - \alpha - 30°$
$= 26.3°$

$\circlearrowleft + \Sigma M_O = 0: \; T \sin 33.7° (1.2) - 18(9.81)(0.75) \cos 60° = 0$

$\underline{T = 99.5 \text{ N}}$

$\Sigma F_x = 0: \; -99.5 \cos 33.7° + O_x = 0$

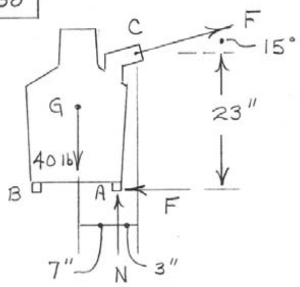
$O_x = 82.8 \text{ N}$

$\Sigma F_y = 0: \; -99.5 \sin 33.7° - 18(9.81) + O_y = 0$

$O_y = 232 \text{ N}$

So $\underline{O = 246 \text{ N @ } 70.3° \text{ CCW from } +x\text{-axis}}$

3/38

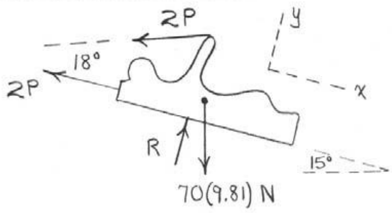


For impending tip, $N_B \to 0$.

$\circlearrowleft + \Sigma M_A = 0: \; 40(7) - F \cos 15°(23) + F \sin 15°(3) = 0$

$\underline{F = 13.06 \text{ lb}}$

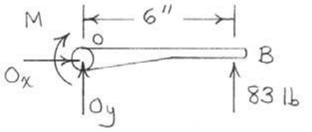
3/39



$\Sigma F_x = 0: \; 70(9.81) \sin 15° - 2P - 2P \cos 18° = 0$
$\underline{P = 45.5 \text{ N}}$

$\Sigma F_y = 0: \; R - 70(9.81) \cos 15° - 2(45.5) \sin 18° = 0$
$\underline{R = 691 \text{ N}}$

3/40 Arm OB:



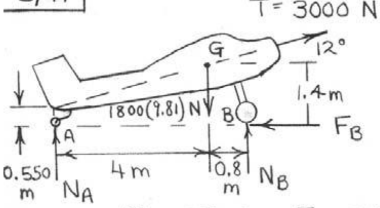
$\circlearrowleft + \Sigma M_O = 0: \; 83(6) - M = 0$

$M = 498$ lb-in. or $\underline{41.5 \text{ lb-ft}}$

$F\cos 20°(15) = M = 498$

$\underline{F = 35.3 \text{ lb}}$

3/41



Engine off: $T = 0$, $F_B = 0$

$\Sigma M_A = 0: \; 1800(9.81)4 - N_B(4.8) = 0 \qquad N_B = 14\,720$ N

$\Sigma F_y = 0: \; N_A + 14\,720 - 1800(9.81) = 0, \qquad N_A = 2940$ N

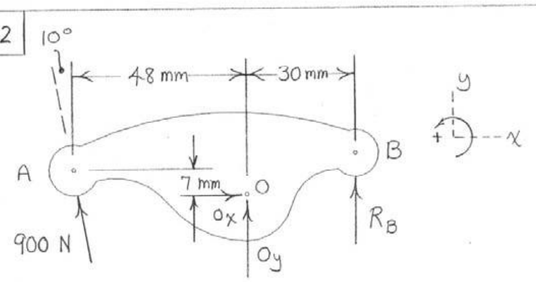
$\Sigma M_A = 0: \; 1800(9.81)4 - N_B'(4.8) + 3000\cos 12°(0.550) = 0$

$N_B' = 15{,}050$ N

$\Sigma F_y = 0: \; N_A' + 15{,}050 - 1800(9.81) + 3000\sin 12° = 0, \; N_A' = 1983$ N

$n_A = \dfrac{N_A' - N_A}{N_A}(100) = \underline{-32.6\%}, \quad n_B = \dfrac{N_B' - N_B}{N_B} = \underline{2.28\%}$

3/42



$\Sigma M_O = 0: \; -900\cos 10°(48) + 900\sin 10°(7)$

$+ R_B(30) = 0, \quad \underline{R_B = 1382 \text{ N}}$

$\Sigma F_x = 0: \; O_x - 900\sin 10° = 0, \quad O_x = 156.3$ N

$\Sigma F_y = 0: \; 900\cos 10° + 1382 + O_y = 0$

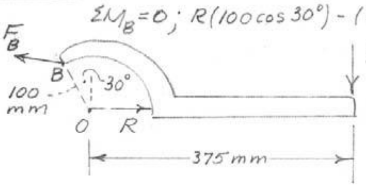
$O_y = -2270$ N

$O = \sqrt{O_x^2 + O_y^2} = \underline{2270 \text{ N}}$

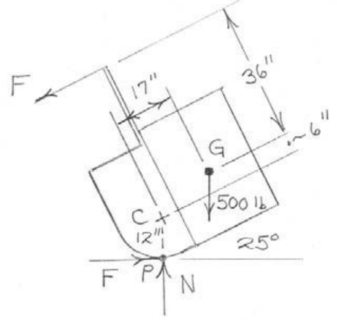
3/43 $M = Fd; \; 80 = P(0.375), \; P = 213$ N

$\Sigma M_B = 0; \; R(100\cos 30°) - (375 + 100\sin 30°)(213) = 0$

$\underline{R = 1047 \text{ N}}$



3/44

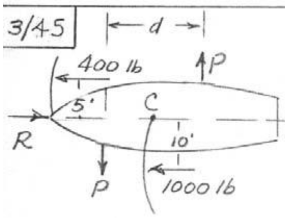


$\circlearrowleft + \Sigma M_P = 0: \; F(36 + 6 + 12\cos 25°) -$

$500[17\cos 25°] + 500[6\sin 25°] = 0$

$\underline{F = 121.7 \text{ lb}}$

3/45

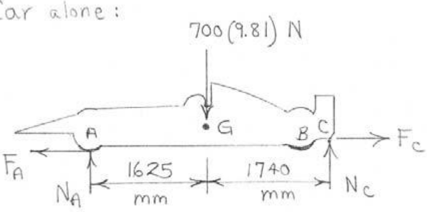


$\Sigma M_C = 0; \; Pd + 400(5) - 1000(10) = 0$

Resultant of lateral forces is couple

$M = Pd = \underline{8000 \text{ lb-ft}}$

3/46 Car alone:

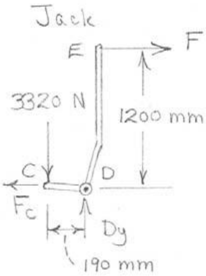


$\circlearrowleft + \Sigma M_A = 0: \; -700(9.81)(1625) + N_C(1625 + 1740) = 0$

$N_C = 3320$ N

(assumes moment of F_C about A is negligible)

Jack

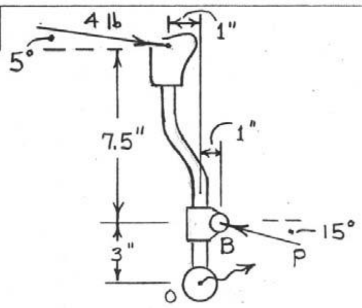


$\circlearrowleft + \Sigma M_D = 0:$

$3320(190) - F(1200) = 0$

$\underline{F = 525 \text{ N}}$

3/47

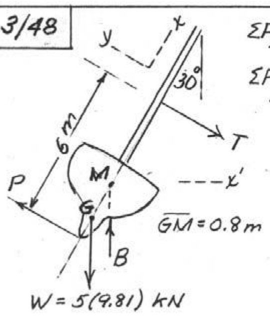


$\circlearrowleft + \Sigma M_o = 0: \ -4\cos 5°(10.5) + 4\sin 5°(1)$

$+ P\cos 15°(3) + P\sin 15°(1) = 0$

$\underline{P = 13.14 \text{ lb}}$

3/48



$\Sigma F_x = 0; \ B = 5(9.81) = 49.05 \text{ kN}$

$\Sigma F_{x'} = 0; \ P = T$

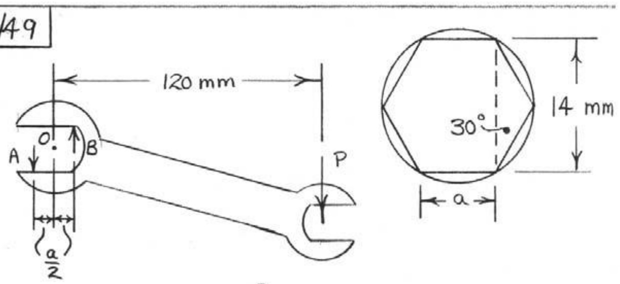
Two couples, so

$\Sigma M = 0; \ 6T - 5(9.81)(0.8)\sin 30° = 0$

$T = \dfrac{5(9.81)(0.8)(0.5)}{6}$

$= \underline{3.27 \text{ kN}}$

3/49



$2a\cos 30° = 14, \quad \dfrac{a}{2} = 4.04 \text{ mm}$

$\circlearrowleft + \Sigma M_O = 0: \ 0.120P - 24 = 0, \quad \underline{P = 200 \text{ N}}$

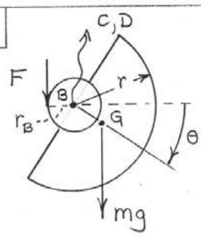
(for wrench and bolt)

For wrench alone,

$\circlearrowleft + \Sigma M_A = 0: \ 200(0.120 + 0.00404) - B(2 \cdot 0.00404) = 0, \quad \underline{B = 3070 \text{ N}}$

$+\uparrow \Sigma F = 0: \ -A + 3070 - 200 = 0, \quad \underline{A = 2870 \text{ N}}$

3/50



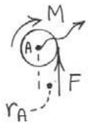
$\overline{BG} = \bar{r} = \frac{3}{8}r$ (from Table D/4)

FBD is of hemisphere, shaft, and gear B.

$\circlearrowleft + \Sigma M_B = 0: \ Fr_B - mg\left(\frac{3}{8}r\cos\theta\right)$

$F = \frac{3}{8}mg\frac{r}{r_B}\cos\theta$

Gear A:

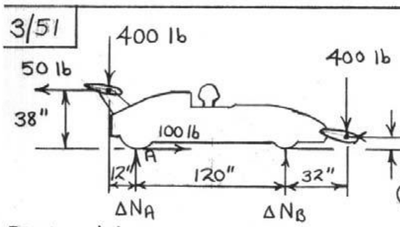


$\circlearrowleft + \Sigma M_B = 0: \ Fr_A - M = 0$

$M = \left(\frac{3}{8}mg\frac{r}{r_B}\cos\theta\right)r_A$

$= \underline{\dfrac{3mgr}{8}\dfrac{r_A}{r_B}\cos\theta}$

3/51



{Without airfoils, $N_A = N_B = 850$ lb

(force changes only)

With airfoils,

$+\uparrow \Sigma F_y = 0: \ \Delta N_A + \Delta N_B - 2(400) = 0$

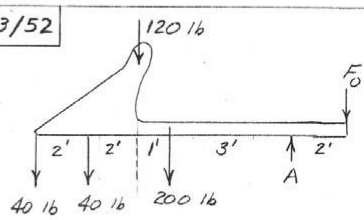
$\circlearrowleft + \Sigma M_A = 0: \ 50(38) + 400(12) + \Delta N_B(120)$

$+ 50(5) - 400(152) = 0$

$\left.\begin{array}{l}\Delta N_A = 351 \text{ lb} \\ \Delta N_B = 449 \text{ lb}\end{array}\right\} \Rightarrow \begin{array}{l} N_A = 850 + 351 = 1201 \text{ lb} \ (48.0\%) \\ \underline{N_B = 850 + 449 = 1299 \text{ lb} \ (52.0\%)}\end{array}$

Note that a 100-lb propulsive force has been added (at A) to maintain equilibrium.

3/52



$\Sigma M_A = 0;$

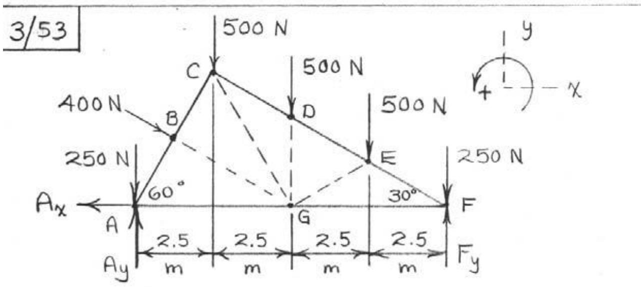
$40(8) + 40(6)$

$+ 120(4) + 200(3)$

$- 2F_0 = 0$

$\underline{F_0 = 820 \text{ lb}}$

3/53



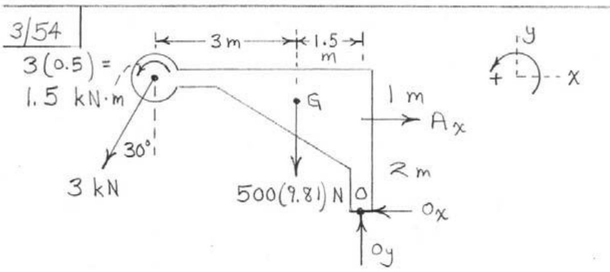
$\Sigma F_x = 0: \; -A_x + 400\cos 30° = 0, \quad \underline{A_x = 346 \text{ N}}$

$\Sigma M_A = 0: \; 400\left(\frac{10}{4}\right) + 500(2.5) + 500(5) + 500(7.5) + 250(10) - 10F_y = 0$

$\underline{F_y = 1100 \text{ N}}$

$\Sigma F_y = 0: -250 - 400\sin 30° - 500(3) - 250 + 1100 + A_y = 0, \quad \underline{A_y = 1100 \text{ N}}$

3/54



$\Sigma M_O = 0: \; -2A + 500(9.81)(1.5) + 1500 + 3000\cos 30°(4.5) + 3000\sin 30°(3) = 0$

$A = 12\,520 \text{ N}$

$\Sigma F_x = 0: \; -3000\sin 30° + 12\,520 - O_x = 0$

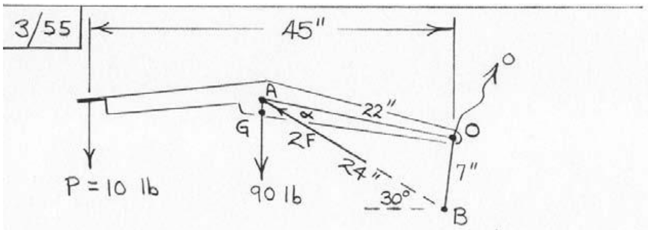
$O_x = 11\,020 \text{ N}$

$\Sigma F_y = 0: \; -3000\cos 30° - 500(9.81) + O_y = 0$

$O_y = 7500 \text{ N}$

$O = \sqrt{11020^2 + 7500^2} = 13\,340 \text{ N or } \underline{13.34 \text{ kN}}$

3/55

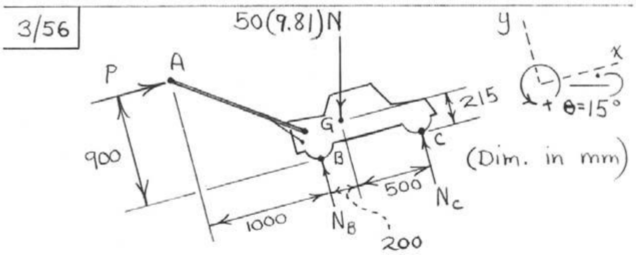


Law of cosines: $7^2 = 22^2 + 24^2 - 2(22)(24)\cos\alpha$

$\alpha = 16.79°$

$\Sigma M_O = 0: \; 10(45) - 2F(22\sin\alpha) + 90(22\cos(30°-\alpha)) = 0, \quad \underline{F = 187.1 \text{ lb}}$

3/56



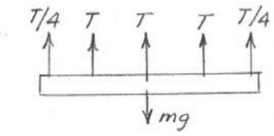
$\Sigma F_x = 0: \; P - 50(9.81)\sin 15° = 0 \quad (1)$

$\Sigma F_y = 0: \; N_B + N_C - 50(9.81)\cos 15° = 0 \quad (2)$

$\Sigma M_C = 0: \; -P(900) - N_B(700) + 50(9.81)[500\cos 15° + 215\sin 15°] = 0 \quad (3)$

Solution to Eqs. (1)-(3):	With $\theta = P = 0$:
$P = 127.0$ N	$P = 0$
$N_B = 214$ N	$N_B = 350$ N
$N_C = 260$ N	$N_C = 140.1$ N

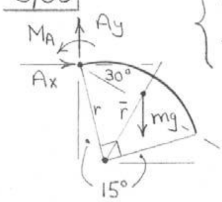
3/57



$\Sigma F = 0; \; \left(3 + \frac{1}{4} + \frac{1}{4}\right)T - mg = 0$

$\underline{T = \frac{2}{7}mg}$

3/58



From Table D/3, $\bar{r} = \frac{r\sin\alpha}{\alpha}$

For $\alpha = \pi/4$, $\bar{r} = 2\sqrt{2}\,r/\pi$

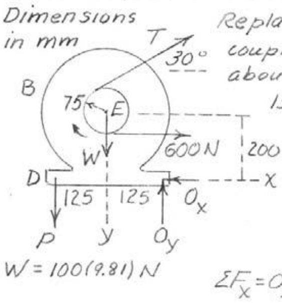
$\Sigma M_A = 0:$

$M_A - mg(r\sin 15° + \bar{r}\cos 60°) = 0$

$\underline{M_A = 0.709\, mgr}$

3/59 Torque $M = 100 \text{ N·m} = (600 - T)(0.225)$, $T = 155.6 \text{ N}$

Dimensions in mm



Replace T by force at E and a couple, so that moment of T about D in CW sense becomes

$155.6(0.2\cos 30° - 0.125\sin 30°) + 155.6(0.075) = 28.89 \text{ N·m}$

$\Sigma M_D = 0; \; 28.89 + 981(0.125) + 600(0.2 - 0.075) - 0.250\,O_y = 0$

$O_y = 906 \text{ N}$

$W = 100(9.81) \text{ N}$

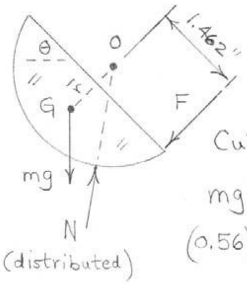
$\Sigma F_x = 0; \; 155.6\cos 30° + 600 - O_x = 0$

$O_x = 735 \text{ N}$

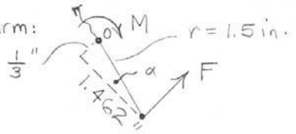
$R = \sqrt{O_x^2 + O_y^2} = \sqrt{(735)^2 + (906)^2} = 1167 \text{ N or } \underline{1.167 \text{ kN}}$

3/60

Cube:



Arm:



$\alpha = \sin^{-1}\dfrac{1/3}{1.5} = 12.84°$

Cube: $\curvearrowleft \Sigma M_O = 0$:

$mg\bar{r}\sin\theta - F(1.462) = 0$

$(0.56)(0.55 \cdot 1.5)\sin\theta - F(1.462) = 0$

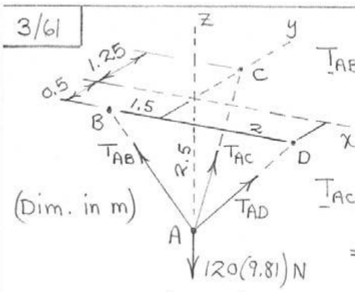
$F = 0.316\sin\theta$ (in lb)

Arm: $\curvearrowleft \Sigma M_O = 0$:

$-M + 0.316\sin\theta\,(1.462) = 0$

$\underline{M = 0.462\sin\theta \text{ lb-in.}}$

3/61



$T_{AB} = T_{AB}\dfrac{-1.5i - 0.5j + 2.5k}{\sqrt{1.5^2 + 0.5^2 + 2.5^2}}$

$= T_{AB}(-0.507i - 0.1690j + 0.845k)$

$T_{AC} = T_{AC}\dfrac{1.25j + 2.5k}{\sqrt{1.25^2 + 2.5^2}}$

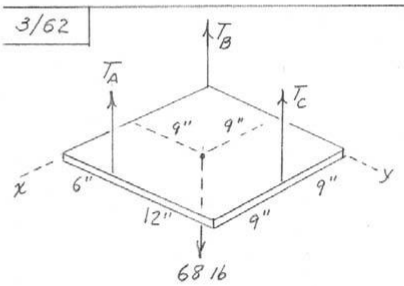
$= T_{AC}(0.447j + 0.894k)$

$T_{AD} = T_{AD}\dfrac{2i - 0.5j + 2.5k}{\sqrt{2^2 + 0.5^2 + 2.5^2}} = T_{AD}(0.617i - 0.1543j + 0.772k)$

$$\begin{cases} \Sigma F_x = 0: -0.507T_{AB} + 0.617T_{AD} = 0 \\ \Sigma F_y = 0: -0.1690T_{AB} + 0.447T_{AC} - 0.1543T_{AD} = 0 \\ \Sigma F_z = 0: 0.845T_{AB} + 0.894T_{AC} + 0.772T_{AD} - 120(9.81) = 0 \end{cases}$$

Solution: $\begin{cases} T_{AB} = 569 \text{ N} \\ T_{AC} = 376 \text{ N} \\ T_{AD} = 467 \text{ N} \end{cases}$

3/62



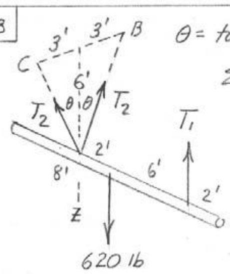
$\Sigma M_x = 0;\ 6T_A + 18T_C - 68(9) = 0,\quad T_A + 3T_C = 102$

$\Sigma M_y = 0;\ -18T_A - 9T_C + 68(9) = 0,\quad 2T_A + T_C = 68$

Solve & get $\underline{T_A = 20.4 \text{ lb}}$, $\underline{T_C = 27.2 \text{ lb}}$.

$\Sigma F_z = 0;\ 20.4 + T_B + 27.2 - 68 = 0,\quad \underline{T_B = 20.4 \text{ lb}}$

3/63



$\theta = \tan^{-1} 3/6 = 26.57°$

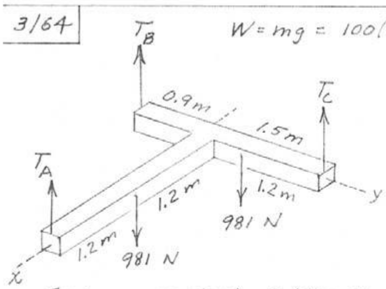
$\Sigma M_{CB} = 0;\ 8T_1 - 620(2) = 0$

$\underline{T_1 = 155 \text{ lb}}$

$\Sigma F_z = 0;\ 620 - 155 - 2T_2\cos\theta = 0$

$T_2 = \dfrac{465}{2\cos 26.57°} = \underline{260 \text{ lb}}$

3/64



$W = mg = 100(9.81) = 981 \text{ N}$

$\Sigma M_y = 0;\ 981(1.2) - 2.4T_A = 0;\quad \underline{T_A = 490 \text{ N}}$

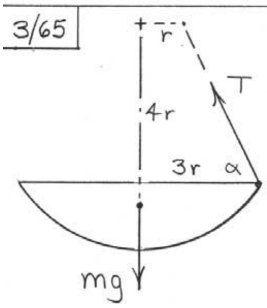
$\Sigma M_x = 0;\ 1.5T_C - 0.9T_B - 981(0.3) = 0$

$\Sigma F_z = 0;\ 491 + T_B + T_C - 2(981) = 0,\quad T_B + T_C = 1472 \text{ N}$

so $1.5T_C - 0.9(1472 - T_C) = 294.3,\quad \underline{T_C = 674 \text{ N}}$

$\underline{T_B = 797 \text{ N}}$

3/65



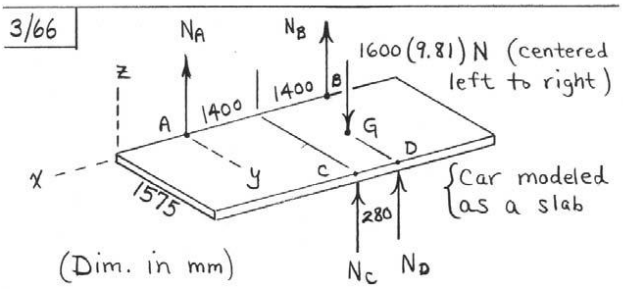
$\alpha = \tan^{-1}\dfrac{4r}{2r} = 63.4°$

$+\uparrow \Sigma F = 0$:

$3(T\sin\alpha) - mg = 0$

$\underline{T = 0.373mg}$

3/66



Jacking at C $(N_D = 0)$:

$\Sigma M_x = 0: \ -1600(9.81)\left(\frac{1575}{2}\right) + N_C(1575) = 0$

$\underline{N_C = 7850 \text{ N}}$

$\Sigma M_y = 0: -1600(9.81)(1680) + N_B(2800) + N_C(1400) = 0$

$\Sigma F_z = 0: \ N_A + N_B + N_C - 1600(9.81) = 0$

$\Rightarrow \underline{N_A = 2350 \text{ N}}, \ \underline{N_B = 5490 \text{ N}}$

Jacking at D $(N_C = 0)$: $\underline{N_D = 7850 \text{ N}}$ {Same as for N_C

$\Sigma M_y = 0: -1600(9.81)(1680) + N_B(2800) + N_D(1680) = 0$

$\Sigma F_z = 0: \ N_A + N_B + N_D - 1600(9.81) = 0$

$\Rightarrow \underline{N_A = 3140 \text{ N}}, \ \underline{N_B = 4710 \text{ N}}$

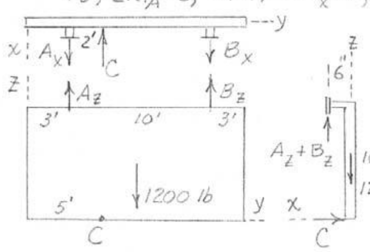
3/67

x-z; $\Sigma M_{AB} = 0$; $10C - 1200(6/12) = 0$, $C = 60$ lb

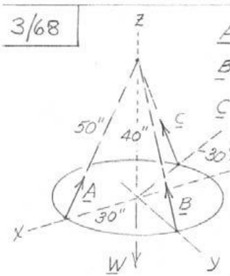
x-y; $\Sigma M_A = 0$; $2(60) - 10B_x = 0$; $\underline{B_x = 12 \text{ lb}}$

$\Sigma F_x = 0$; $A_x + 12 - 60 = 0$

$\underline{A_x = 48 \text{ lb}}$



3/68



$\underline{A} = \frac{A}{5}(-3\underline{i} + 4\underline{k})$

$\underline{B} = \frac{B}{5}(-3\underline{j} + 4\underline{k})$

$\underline{C} = \frac{C}{5}(3\underline{i}\cos 30° + 3\underline{j}\sin 30° + 4\underline{k})$

$\underline{W} = -600\underline{k}$ lb

$\Sigma \underline{F} = 0; \ \frac{1}{5}\left(-3A + \frac{3\sqrt{3}}{2}C\right)\underline{i} + \frac{1}{5}\left(-3B + \frac{3}{2}C\right)\underline{j}$

$+ \frac{1}{5}(4A + 4B + 4C - 5[600])\underline{k} = \underline{0}$

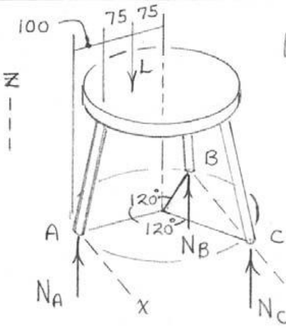
Thus $A = \frac{\sqrt{3}}{2}C$, $B = \frac{C}{2}$, $4(A+B+C) = 3000$

$4\left(\frac{\sqrt{3}}{2} + \frac{1}{2} + 1\right)C = 3000, \ C = \frac{3000}{2(3+\sqrt{3})} = \underline{317 \text{ lb}}$

$B = \underline{158 \text{ lb}}$

$A = \underline{275 \text{ lb}}$

3/69



Note: x-axis is $\parallel$ BC.

$N_B = N_C = N$, by symmetry.

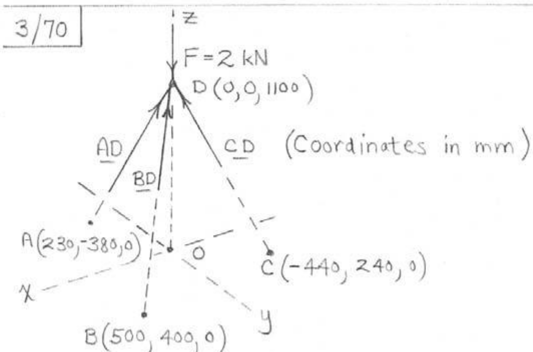
$\Sigma M_x = 0: \ -L(175) + 2N(250 + 250\cos 60°) = 0$

$\underline{N = 0.233L = N_B = N_C}$

$\Sigma F_z = 0: \ N_A + 2(0.233L) - L = 0$

$\underline{N_A = 0.533L}$

3/70



(Coordinates in mm)

$\underline{AD} = AD\dfrac{-230\underline{i} + 380\underline{j} + 1100\underline{k}}{\sqrt{230^2 + 380^2 + 1100^2}} = AD(-0.1939\underline{i} + 0.320\underline{j} + 0.927\underline{k})$

$\underline{BD} = BD\dfrac{-500\underline{i} - 400\underline{j} + 1100\underline{k}}{\sqrt{500^2 + 400^2 + 1100^2}} = BD(-0.393\underline{i} - 0.314\underline{j} + 0.864\underline{k})$

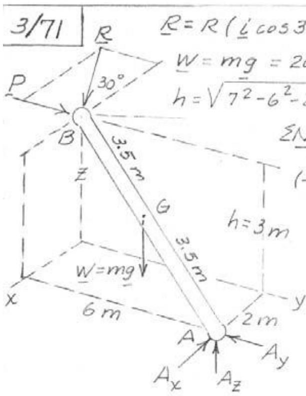
$\underline{CD} = CD\dfrac{440\underline{i} - 240\underline{j} + 1100\underline{k}}{\sqrt{440^2 + 240^2 + 1100^2}} = CD(0.364\underline{i} - 0.1985\underline{j} + 0.910\underline{k})$

From $\Sigma \underline{F} = \underline{0}$: $\begin{cases} -0.1939AD - 0.393BD + 0.364CD = 0 \\ 0.320AD - 0.314BD - 0.1985CD = 0 \\ 0.927AD + 0.864BD + 0.910CD - 2 = 0 \end{cases}$

Solution: $\underline{AD = 0.925 \text{ kN}}$, $\underline{BD = 0.376 \text{ kN}}$, $\underline{CD = 0.898 \text{ kN}}$

(all compression)

3/71



$\underline{R} = R(\underline{i}\cos 30° + \underline{j}\sin 30°) = \frac{R}{2}(\sqrt{3}\underline{i} + \underline{j})$

$\underline{W} = m\underline{g} = 200(9.81)(-\underline{k}) = -1962\underline{k}$ N

$h = \sqrt{7^2 - 6^2 - 2^2} = 3$ m

$\Sigma \underline{M}_A = \underline{0}; \ \underline{r}_{AG} \times \underline{W} + \underline{r}_{AB} \times (\underline{P} + \underline{R}) = \underline{0}$

$(-1\underline{i} - 3\underline{j} + 1.5\underline{k}) \times (-1962\underline{k})$

$+ (-2\underline{i} - 6\underline{j} + 3\underline{k}) \times \left(P\underline{j} + \frac{R\sqrt{3}}{2}\underline{i} + \frac{R}{2}\underline{j}\right) = \underline{0}$

Simplify & get

$(5886 - 3P - 3R/2)\underline{i}$

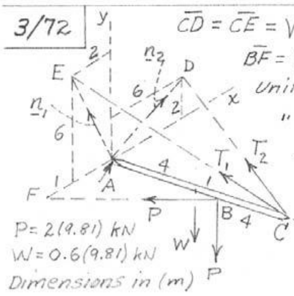
$+ (-1962 + 3\sqrt{3}R/2)\underline{j}$

$+ (-2P + R + 3\sqrt{3}R)\underline{k} = 0$

$R = \frac{2(1962)}{3\sqrt{3}} = \underline{755 \text{ N}}$

$3P = 5886 - \frac{3}{2}755$, $P = \underline{1584 \text{ N}}$

3/72



$\overline{CD} = \overline{CE} = \sqrt{6^2+2^2+9^2} = 11\ m$

$\overline{BF} = \sqrt{3^2+5^2} = 5.83\ m$

Unit vector $\underline{n}_1 = (-\underline{i}+3\underline{j})/\sqrt{10}$

" " $\underline{n}_2 = (3\underline{i}+\underline{j})/\sqrt{10}$

$\Sigma M_{AD} = 0;$

$9\underline{k} \times \frac{T_1}{11}(-2\underline{i}+6\underline{j}-9\underline{k})\cdot(3\underline{i}+\underline{j})/\sqrt{10}$

$+5\underline{k} \times \frac{2(9.81)}{5.83}(-3\underline{i}-5\underline{k})\cdot(3\underline{i}+\underline{j})/\sqrt{10}$

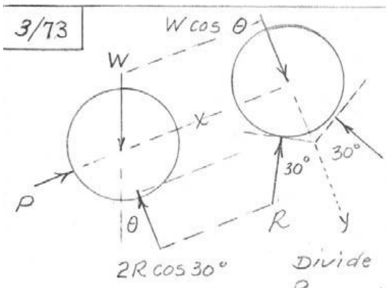
$+5\underline{k} \times 2(9.81)(-\underline{j})\cdot(3\underline{i}+\underline{j})/\sqrt{10}$

$+4.5\underline{k} \times 0.6(9.81)(-\underline{j})\cdot(3\underline{i}+\underline{j})/\sqrt{10} = 0$

Simplify & get $\frac{180T_1}{11\sqrt{10}} + \frac{294.3}{5.83\sqrt{10}} = \frac{373.8}{\sqrt{10}}$, $\underline{T_1 = 19.76\ kN}$

(Similarly, if T_2 is desired, $\Sigma M_{AE} = 0$ will give $T_2 = 16.86\ kN$)

3/73



$\Sigma F_y = 0;$

$2R\cos 30° - W\cos\theta = 0$

$R\sqrt{3} = W\cos\theta$

$\Sigma F_x = 0;$

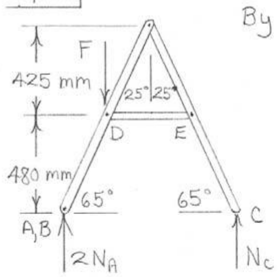
$P - W\sin\theta = 0$

Divide & get

$\frac{P}{R\sqrt{3}} = \tan\theta$

so with $P = R$, $\theta = \tan^{-1} 1/\sqrt{3} = \underline{30°}$

3/74



By inspection, $N_A = N_B$.

$\curvearrowleft \Sigma M_C = 0: -2N_A(2\cdot 905\tan 25°)$

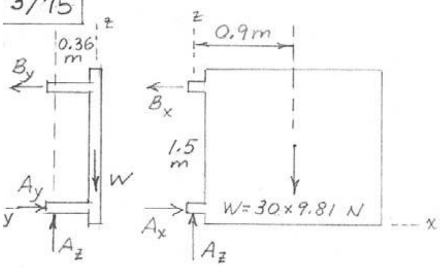
$+F(905\tan 25° + 425\tan 25°) = 0$

$\underline{N_A = 0.367F = N_B}$

$+\uparrow \Sigma F = 0: \quad 2(0.367F) + N_C - F = 0$

$\underline{N_C = 0.265F}$

3/75

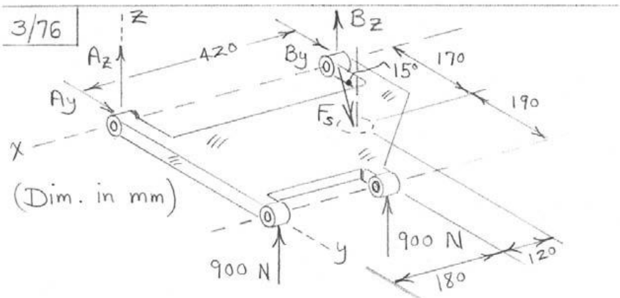


$x\text{-}z;\ \Sigma M_A = 0;\ 1.5B_x - 0.9(30)(9.81) = 0,\ B_x = 176.6\ N$

$y\text{-}z;\ \Sigma M_A = 0;\ 1.5B_y - 0.36(30)(9.81) = 0,\ B_y = 70.6\ N$

$B = \sqrt{176.6^2 + 70.6^2} = \underline{190.2\ N}$

3/76



$\Sigma M_x = 0:\ 2(900)(360) - F_s\cos 15°(170) = 0,\ \underline{F_s = 3950\ N}$

$\Sigma M_y = 0:\ B_z(420) + 900(180) - 3950\cos 15°(300) = 0$

$B_z = 2340\ N$

$\Sigma M_z = 0:\ -B_y(420) - 3950\sin 15°(300) = 0,\ B_y = -730\ N$

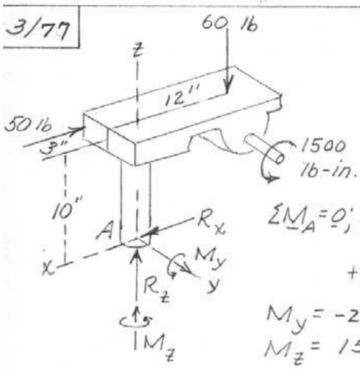
$\Sigma F_y = 0:\ A_y - 730 + 3950\sin 15° = 0,\quad A_y = -292\ N$

$\Sigma F_z = 0:\ A_z + 2340 - 3950\cos 15° + 1800 = 0,\ A_z = -325\ N$

$F_A = \sqrt{A_y^2 + A_z^2} = \underline{437\ N}$

$F_B = \sqrt{B_y^2 + B_z^2} = \underline{2450\ N}$

3/77



$\Sigma \underline{M}_A = \underline{0};\ [-60(12) - 50(10) + 1500 + M_y]\underline{j}$

$+ [-50(3) + M_z]\underline{k} = \underline{0}$

$M_y = -280\ lb\text{-}in.$

$M_z = 150\ lb\text{-}in$

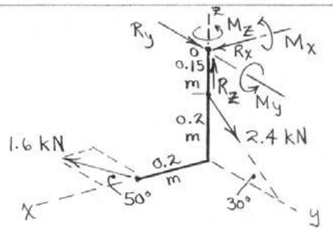
$\underline{\underline{M} = -280\underline{j} + 150\underline{k}\ \ lb\text{-}in.}$

$\Sigma \underline{F} = \underline{0};\ (R_x - 50)\underline{i} + (R_z - 60)\underline{k} = \underline{0}$

$R_x = 50\ lb,\ R_z = 60\ lb$

$\underline{\underline{R} = 50\underline{i} + 60\underline{k}\ \ lb}$

3/78



$\Sigma F_x = 0: R_x + 1.6\cos 50°, \quad R_x = -1.028 \text{ kN}$

$\Sigma F_y = 0: R_y + 2.4\cos 30° - 1.6\sin 50° = 0, \quad R_y = -0.853 \text{ kN}$

$\Sigma F_z = 0: R_z - 2.4\sin 30° = 0, \quad R_z = 1.2 \text{ kN}$

$R = \sqrt{R_x^2 + R_y^2 + R_z^2} = \underline{1.796 \text{ kN}}$

$\Sigma M_{O_x} = 0: M_x + 2.4\cos 30°(0.15) - 1.6\sin 50°(0.35) = 0$

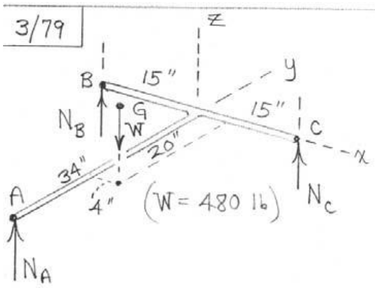
$M_x = 0.1172 \text{ kN·m}$

$\Sigma M_{O_y} = 0: M_y - 1.6\cos 50°(0.35) = 0, \quad M_y = 0.360 \text{ kN·m}$

$\Sigma M_{O_z} = 0: M_z - 1.6\sin 50°(0.2) = 0, \quad M_z = 0.245 \text{ kN·m}$

$M = \sqrt{M_x^2 + M_y^2 + M_z^2} = \underline{0.451 \text{ kN·m}}$

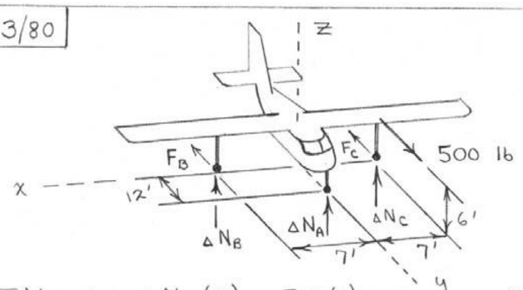
3/79



$$\left.\begin{aligned} \Sigma F_z = 0:&\ N_A + N_B + N_C - 480 = 0 \\ \Sigma M_x = 0:&\ 480(20) - N_A(34) = 0 \\ \Sigma M_y = 0:&\ N_B(15) - N_C(15) + 480(4) = 0 \end{aligned}\right\}$$

Solution : $\begin{cases} N_A = 282 \text{ lb} \\ N_B = 34.8 \text{ lb} \\ N_C = 162.8 \text{ lb} \end{cases}$

3/80

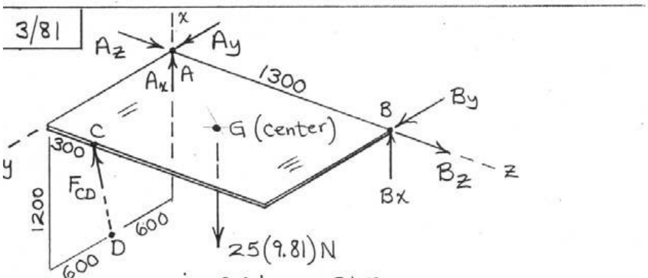


$\Sigma M_x = 0: \Delta N_A(12) - 500(6) = 0, \quad \underline{\Delta N_A = 250 \text{ lb}}$

$$\left.\begin{aligned} \Sigma F_z = 0:&\ \Delta N_A + \Delta N_B + \Delta N_C = 0 \\ \Sigma M_y = 0:&\ \Delta N_C(7) - \Delta N_B(7) = 0 \end{aligned}\right\} \quad \Delta N_B = \Delta N_C = \underline{-125 \text{ lb}}$$

More information would be required to determine F_B and F_C. x-components of friction at B and C are possible.

3/81



$\mathbf{F}_{CD} = F\left[\dfrac{1.2\mathbf{i} + 0.6\mathbf{j} + 0.3\mathbf{k}}{\sqrt{1.2^2 + 0.6^2 + 0.3^2}}\right] = F(0.873\mathbf{i} + 0.436\mathbf{j} + 0.218\mathbf{k})$

$\Sigma M_z = 0: 25(9.81)(0.6) - 0.873F(1.2) = 0$

$\underline{F = 140.5 \text{ N}}$

$\Sigma M_y = 0: B_x(1.3) - 25(9.81)(0.65) + 0.873F(0.3) = 0$

$B_x = 94.3 \text{ N}$

$\Sigma F_x = 0: A_x + 94.3 + 0.873F - 25(9.81) = 0$

$A_x = 28.3 \text{ N}$

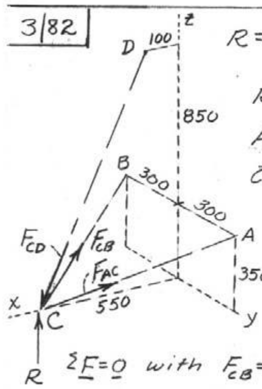
$\Sigma M_x = 0: -B_y(1.3) + 0.218F(0.6) = 0$

$B_y = 14.15 \text{ N}$

$\Sigma F_y = 0: A_y + 14.15 + 0.436F = 0, \quad A_y = -75.5 \text{ N}$

$A_n = \sqrt{75.5^2 + 28.3^2} = \underline{80.6 \text{ N}}, \quad B_n = \sqrt{94.3^2 + 14.15^2} = \underline{95.4 \text{ N}}$

3/82



$R = \frac{1}{3}mg$; From Table C2 for Mars $g = 3.73 \text{ m/s}^2$

$R = \frac{1}{3}600(3.73) = 746 \text{ N}$

$\overline{AC} = \sqrt{(550)^2 + (300)^2 + (350)^2} = 718 \text{ mm}$

$\overline{CD} = \sqrt{(450)^2 + (1200)^2} = 1282 \text{ mm}$

$\mathbf{F}_{AC} = \frac{F_{AC}}{718}(-550\mathbf{i} + 300\mathbf{j} + 350\mathbf{k})$

$\mathbf{F}_{CB} = \frac{F_{CB}}{718}(-550\mathbf{i} - 300\mathbf{j} + 350\mathbf{k})$

$\mathbf{F}_{CD} = \frac{F_{CD}}{1282}(450\mathbf{i} - 1200\mathbf{k})$

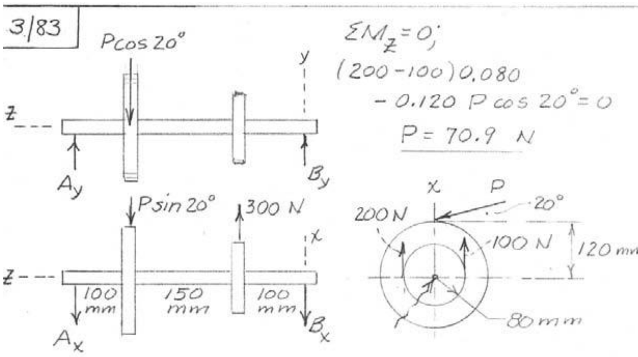
$\Sigma \mathbf{F} = \mathbf{0}$ with $F_{CB} = F_{AC}$ gives upon collecting terms

$\left(-\frac{2F_{AC}}{718}550 + \frac{F_{CD}}{1282}450\right)\mathbf{i} + \left(746 + \frac{2F_{AC}}{718}350 - \frac{F_{CD}}{1282}1200\right)\mathbf{k} = \mathbf{0}$

Equate coefficients to zero & solve simultaneously to get $F_{CD} = \underline{1046 \text{ N}}$ compression

$F_{AC} = F_{CB} = \underline{240 \text{ N}}$ tension

3/83



$\Sigma M_z = 0;$

$(200 - 100)0.080 - 0.120P\cos 20° = 0$

$P = 70.9 \text{ N}$

y-z; $\Sigma M_A = 0;\ 0.35B_y - 70.9\cos 20°(0.1) = 0, \quad B_y = 19.05 \text{ N}$

$\Sigma F_y = 0;\ A_y + 19.05 - 70.9\cos 20° = 0, \quad A_y = 47.6 \text{ N}$

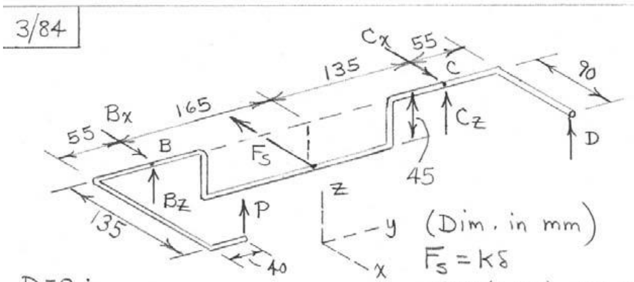
x-z; $\Sigma M_A = 0;\ 300(0.25) - 70.9\sin 20°(0.1) - 0.35B_x = 0$

$B_x = 207 \text{ N}$

$\Sigma F_x = 0;\ A_x + 70.9\sin 20° + 207 - 300 = 0; \quad A_x = 68.4 \text{ N}$

$A = \sqrt{68.4^2 + 47.6^2} = \underline{83.3 \text{ N}}, \quad B = \sqrt{207^2 + 19.05^2} = \underline{208 \text{ N}}$

3/84



(Dim. in mm)

$F_s = k\delta = 900(0.060) = 54$ N

D=0 :

$\Sigma M_{BC} = 0: \ -P(135) + 54(45) = 0, \quad \underline{P_{min} = 18 \text{ N}}$

$\Sigma M_{B_x} = 0: \ -18(15) + C_z(300) = 0, \quad C_z = 0.9$ N

$\Sigma M_{B_z} = 0: \ 54(165) - C_x(300) = 0, \quad C_x = 29.7$ N

$\Sigma F_x = 0: \ 29.7 + B_x - 54 = 0, \quad B_x = 24.3$ N

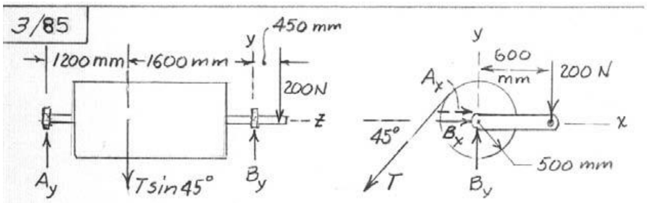
$\Sigma F_z = 0: \ 0.9 + B_z + 18 = 0, \quad B_z = -18.9$ N

$B = \sqrt{B_x^2 + B_z^2} = \underline{30.8 \text{ N}}, \ C = \sqrt{C_x^2 + C_z^2} = \underline{29.7 \text{ N}}$

If $P = P_{min}/2 = 18/2 = 9$ N, $(D \neq 0)$:

$\Sigma M_{BC} = 0: -9(135) + 54(45) - D(90) = 0, \ \underline{D = 13.5 \text{ N}}$

3/85



$\Sigma M_z = 0; \ 0.500T - 0.600(200) = 0, \quad T = 240$ N

$\Sigma M_x = 0; \ 2.800A_y + 0.450(200) - 240(0.707)(1.600) = 0$

$A_y = 64.8$ N

$\Sigma F_y = 0; \ 64.8 - 240(0.707) + B_y - 200 = 0, \ B_y = 305$ N

$\Sigma M_y = 0; \ 240(0.707)(1.600) - 2.800A_x = 0, \ A_x = 97.0$ N

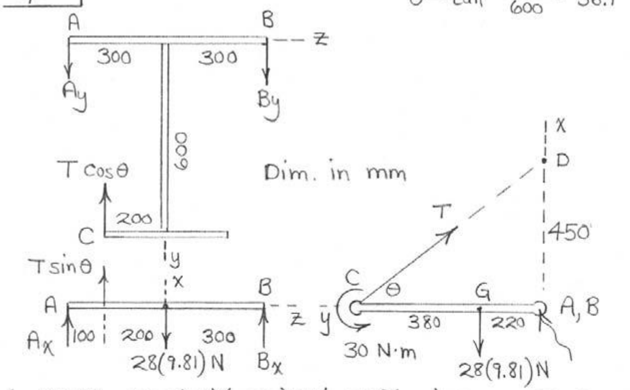
$\Sigma F_x = 0; \ 97.0 + B_x - 240(0.707) = 0, \quad B_x = 72.7$ N

$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(97.0)^2 + (64.8)^2} = \underline{116.7 \text{ N}}$

$B = \sqrt{B_x^2 + B_y^2} = \sqrt{(72.7)^2 + (305)^2} = \underline{313 \text{ N}}$

3/86

$\theta = \tan^{-1}\frac{450}{600} = 36.9°$



$(x\text{-}y) \ \Sigma M_z = 0: 28(9.81)(0.220) - T\sin 36.9°(0.600) + 30 = 0, \quad T = 251$ N

$(x\text{-}z) \ \Sigma M_B = 0: 28(9.81)(0.300) - 251\sin 36.9°(0.500) - 0.600A_x = 0, \ A_x = 11.74$ N

$\Sigma F_x = 0: \ 11.74 + 251\sin 36.9° - 28(9.81) + B_x = 0, \quad B_x = 112.2$ N

$(y\text{-}z) \ \Sigma M_B = 0: \ 251\cos 36.9°(0.500) - 0.6A_y = 0, \quad A_y = 167.5$ N

$\Sigma F_y = 0: \ 167.5 + B_y - 251\cos 36.9° = 0, \quad B_y = 33.5$ N

$A = \sqrt{11.74^2 + 167.5^2} = \underline{167.9 \text{ N}}$

$B = \sqrt{112.2^2 + 33.5^2} = \underline{117.1 \text{ N}}$

Couple may be applied at any place on rigid body with the same external effect.

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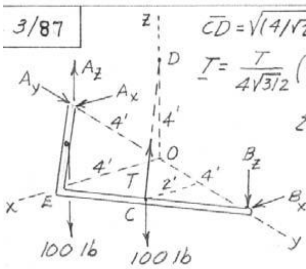


$\overline{CD} = \sqrt{(4/\sqrt{2})^2 + 4^2} = 4\sqrt{3/2}$ ft

$\underline{T} = \frac{T}{4\sqrt{3/2}}(-2\underline{i} - 2\underline{j} + 4\underline{k}) = \frac{T}{\sqrt{6}}(-\underline{i} - \underline{j} + 2\underline{k})$

$\Sigma M_{AB} = 0; \ 200(2) - T_z(2) = 0$

$T_z = \frac{2T}{\sqrt{6}} = 200, \ T = 100\sqrt{6}$ lb

$\underline{T = 245 \text{ lb}}$

$(\Sigma M_B)_x = 0; \ 100(2) + 100(6) - 200(2) - 8A_z = 0, \ A_z = 50$ lb

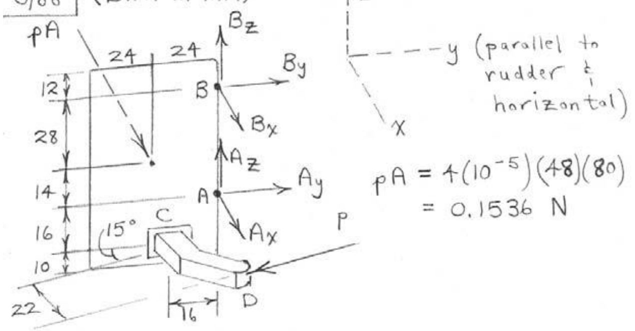
$\Sigma F_y = 0; \ A_y - \frac{100\sqrt{6}}{\sqrt{6}} = 0, \quad A_y = 100$ lb

$(\Sigma M_B)_z = 0; \ 8A_x - \frac{100\sqrt{6}}{\sqrt{6}}(2) - \frac{100\sqrt{6}}{\sqrt{6}}(2) = 0, \ A_x = 50$ lb

$A = \sqrt{50^2 + 100^2 + 50^2} = \underline{122.5 \text{ lb}}$

3/88

(Dim. in mm)



$pA = 4(10^{-5})(48)(80) = 0.1536$ N

$\Sigma M_{AB} = 0: \ -P(22 - 16\sin 15°) + 0.1536(24) = 0$

$\underline{P = 0.206 \text{ N}}$

$\Sigma M_{B_x} = 0: \ A_y(42) - 0.206\cos 15°(58) = 0$

$\underline{A_y = 0.275 \text{ N}}$

$\Sigma M_{A_x} = 0: \ -B_y(42) - 0.206\cos 15°(16) = 0$

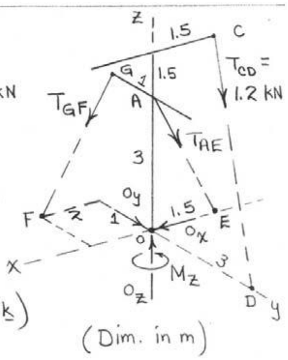
$\underline{B_y = -0.0760 \text{ N}}$

3/89 From Prob. 2/105,

$\underline{T}_{CD} = 0.321\underline{i} + 0.641\underline{j} - 0.962\underline{k}$ kN

$\underline{T}_{AE} = T_{AE}\dfrac{-1.5\underline{i} - 3\underline{k}}{\sqrt{1.5^2 + 3^2}} = T_{AE}(-0.447\underline{i} - 0.894\underline{k})$

$\underline{T}_{GF} = T_{GF}\dfrac{2\underline{i} - 3\underline{k}}{\sqrt{2^2 + 3^2}} = T_{GF}(0.555\underline{i} - 0.832\underline{k})$



$\Sigma \underline{M}_O = \underline{0}$: $\underline{OC} \times \underline{T}_{CD} + \underline{OA} \times \underline{T}_{AE} + \underline{OG} \times \underline{T}_{GF} + M_z\underline{k} = \underline{0}$

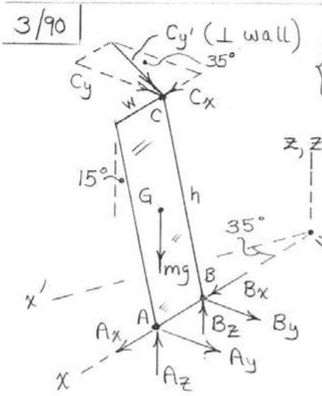
$(-1.5\underline{i} + 4.5\underline{k}) \times (0.321\underline{i} + 0.641\underline{j} - 0.962\underline{k}) + 3\underline{k} \times T_{AE}(-0.447\underline{i} - 0.894\underline{k}) + (-\underline{j} + 3\underline{k}) \times T_{GF}(0.555\underline{i} - 0.832\underline{k})$

$+ M_z\underline{k} = \underline{0} \Rightarrow \begin{cases} 0.832T_{GF} - 2.89 = 0 \\ 1.664\,T_{GF} - 1.342T_{AE} = 0 \\ 0.555\,T_{GF} - 0.962 + M_z = 0 \end{cases}$

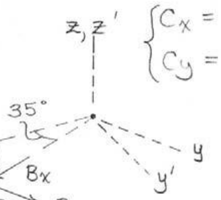
Solve to obtain $\underline{T_{GF} = 3.47 \text{ kN}}$, $\underline{T_{AE} = 4.30 \text{ kN}}$,

$\underline{M_z = -0.962 \text{ kN}\cdot\text{m}}$

3/90



$\begin{cases} xyz: \text{ door-based} \\ x'y'z': \text{ wall-based} \end{cases}$



$\begin{cases} C_x = C_y' \sin 35° \\ C_y = C_y' \cos 35° \end{cases}$

$\Sigma M_x = 0$: $mg\frac{h}{2}\sin 15° - C_y h \cos 15° = 0$, $\underline{C_y = 0.1340\,mg}$

$C_y' = \dfrac{C_y}{\cos 35°} = \underline{0.1636\,mg}$, $\underline{C_x = C_y \tan 35° = 0.0938\,mg}$

$\Sigma M_{B_z} = 0$: $C_x h \sin 15° + A_y w = 0$, $\underline{A_y = -0.0243\,mg\frac{h}{w}}$

$\Sigma M_{B_y} = 0$: $mg\frac{w}{2} + C_x h \cos 15° - A_z w = 0$

$\underline{A_z = mg\left(\frac{1}{2} + 0.0906\frac{h}{w}\right)}$

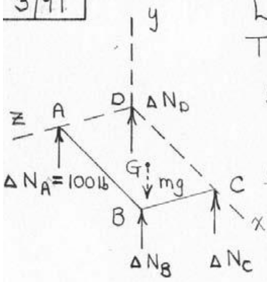
$\Sigma M_{A_z} = 0$: $-B_y w - C_y w + C_x h \sin 15° = 0$

$\underline{B_y = mg\left(0.0243\frac{h}{w} - 0.1340\right)}$

$\Sigma M_{A_y} = 0$: $B_z w - mg\frac{h}{2} + C_x h \cos 15° = 0$

$\underline{B_z = mg\left(\frac{1}{2} - 0.0906\frac{h}{w}\right)}$

3/91



Location of G does not change. Thus,

$\underline{\Delta N_D = -100 \text{ lb}}$ (preserves total rear-axle loading)

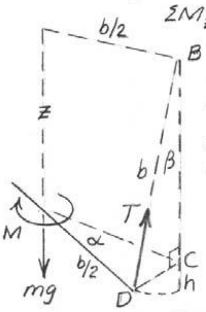
$\underline{\Delta N_B = -100 \text{ lb}}$ (preserves total right-side loading)

$\underline{\Delta N_C = 100 \text{ lb}}$ (preserves total normal force; preserves total front-axle loading)

(Note: The results for ΔN_B & ΔN_C hold only if the track (distance between tire centers) at the front is equal to that at the rear.)

3/92 $\Sigma F_z = 0$; $2T\cos\beta - mg = 0$ ---------(1)

$\Sigma M_z = 0$; $2T\sin\beta\cos\frac{\alpha}{2}\left(\frac{b}{2}\right) - M = 0$ ---(2)



$\overline{CD} = 2\,\frac{b}{2}\sin\frac{\alpha}{2} = b\sin\beta$, $\beta = \frac{\alpha}{2}$ -- (3)

Divide (2) by (1) & substitute (3) & get

$\dfrac{2T\frac{b}{2}\sin\beta\cos\beta}{2T\cos\beta} = \dfrac{M}{mg}$, $\sin\beta = \dfrac{2M}{bmg}$

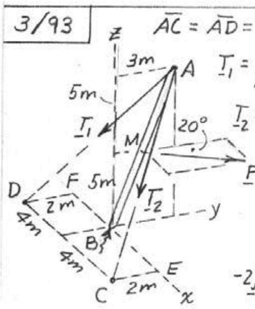
Thus $\cos\beta = \sqrt{1 - \left(\frac{2M}{bmg}\right)^2}$

& $h = b(1 - \cos\beta)$

so $\underline{h = b\left(1 - \sqrt{1 - \left(\frac{2M}{bmg}\right)^2}\right)}$

For $h \to b$, $\cos\beta \to 0$, $\sin\beta \to \pi/2$ & $\underline{M \to \frac{bmg}{2}}$

3/93 $\overline{AC} = \overline{AD} = \sqrt{4^2 + 5^2 + 10^2} = 11.87$ m ; $|\underline{P}| = 20$ kN



$\underline{T}_1 = \dfrac{T_1}{11.87}(-4\underline{i} - 5\underline{j} - 10\underline{k})$; $\sin 20° = 0.3420$

$\underline{T}_2 = \dfrac{T_2}{11.87}(4\underline{i} - 5\underline{j} - 10\underline{k})$; $\cos 20° = 0.9397$

$\Sigma M_x = 0$; $\underline{r}_{EC} \times \underline{T}_2 \cdot \underline{i} + \underline{r}_{FD} \times \underline{T}_1 \cdot \underline{i} + \underline{r}_{BM} \times \underline{P} \cdot \underline{i} = 0$

$-2\underline{j} \times \frac{T_2}{11.87}(4\underline{i} - 5\underline{j} - 10\underline{k}) \cdot \underline{i}$

$-2\underline{j} \times \frac{T_1}{11.87}(-4\underline{i} - 5\underline{j} - 10\underline{k}) \cdot \underline{i} + (1.5\underline{j} + 5\underline{k}) \times 20(0.342\underline{i} + 0.9397\underline{j}) \cdot \underline{i} = 0$

Simplify & get $T_1 + T_2 = 55.79$ ---- (1)

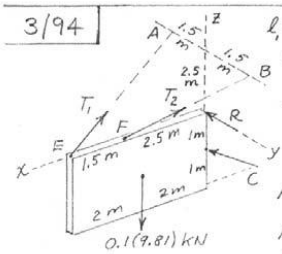
$\Sigma M_z = 0$; $\underline{r}_{BA} \times (\underline{T}_1 + \underline{T}_2) \cdot \underline{k} + \underline{r}_{BM} \times \underline{P} \cdot \underline{k} = 0$

$(3\underline{j} + 10\underline{k}) \times \frac{1}{11.87}([-4T_1 + 4T_2]\underline{i} + [-5T_1 - 5T_2]\underline{j} - [10T_1 + 10T_2]\underline{k}) \cdot \underline{k} - 20(0.3420)(1.5) = 0$

Simplify to $T_1 - T_2 = 10.14$ ---- (2)

Solve (1) & (2) & get $\underline{T_1 = 33.0 \text{ kN}}$, $\underline{T_2 = 22.8 \text{ kN}}$

3/94



$\ell_1 = \overline{AE} = \sqrt{4^2 + 1.5^2 + 2.5^2} = 4.95\ m$

$\ell_2 = \overline{BF} = \sqrt{2.5^2 + 1.5^2 + 2.5^2} = 3.84\ m$

$\underline{T}_1 = \frac{T_1}{\ell_1}(-4\underline{i} - 1.5\underline{j} + 2.5\underline{k})$

$\underline{T}_2 = \frac{T_2}{\ell_2}(-2.5\underline{i} + 1.5\underline{j} + 2.5\underline{k})$

Note: $\underline{T}_1$, $\underline{T}_2$, $\underline{R}$, and weight all pass through x-axis, so $\underline{C}$ must also. Thus $C_y = 0$

$\Sigma M_{AB} = 0;\ C_x(3.5) - 9.81(2) = 0,\quad C_x = 0.561\ kN$

$\Sigma M_z = 0;\ 4\underline{i} \times \frac{T_1}{\ell_1}(-1.5\underline{j}) + 2.5\underline{i} \times \frac{T_2}{\ell_2}(1.5\underline{j}) = \underline{0},\quad 8T_1/\ell_1 = 5T_2/\ell_2$

$\Sigma F_x = 0;\ -\frac{T_1}{\ell_1}(4) - \frac{T_2}{\ell_2}(2.5) + 0.561 = 0,\quad 8T_1/\ell_1 + 5T_2/\ell_2 = 1.121\ kN$

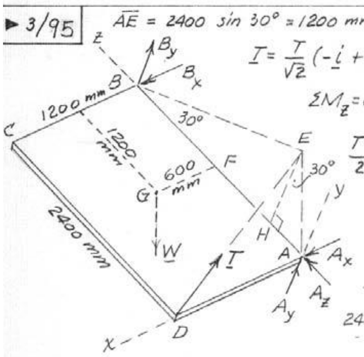
solve & get $T_1 = 1.121\,\ell_1/16 = \underline{0.347\ kN}$, $T_2 = \frac{1.121}{10}\ell_2 = \underline{0.431\ kN}$

$\Sigma F_y = 0;\ \frac{1.121}{16}\ell_1\frac{1.5}{\ell_1} - \frac{1.121}{10}\ell_2\frac{1.5}{\ell_2} + R = 0,\quad \underline{R = 0.0631\ kN}$

$\Sigma F_z = 0;\ \frac{1.121}{16}\ell_1\frac{2.5}{\ell_1} + \frac{1.121}{10}\ell_2\frac{2.5}{\ell_2} + C_z - 0.981 = 0,\quad C_z = 0.526\ kN$

Thus $C = \sqrt{(0.561)^2 + (0.526)^2} = \underline{0.768\ kN}$

►3/95



$\overline{AE} = 2400\sin 30° = 1200\ mm$, $\overline{AH} = 600\ mm$, $\overline{HE} = 1200\cos 30° = 600\sqrt{3}\ mm$

$\underline{T} = \frac{T}{\sqrt{2}}(-\underline{i} + \frac{\sqrt{3}}{2}\underline{j} + \frac{1}{2}\underline{k})$

$\Sigma M_z = 0;\ T_y\overline{AD} - W_y\overline{GF} = 0$

$\frac{T\sqrt{3}}{2\sqrt{2}}(1200) = 40(9.81)\frac{\sqrt{3}}{2}(600)$

$T = 20(9.81)\sqrt{2} = \underline{277\ N}$

$\Sigma M_x = 0;\ -B_y\overline{AB} + W_y\overline{FA} = 0$

$2400B_y = 40(9.81)\frac{\sqrt{3}}{2}(1200)$

$B_y = 98.1\sqrt{3} = 169.9\ N$

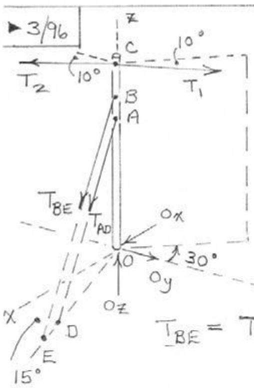
$\Sigma M_y = 0;\ B_x\overline{AB} + W_z\overline{GF} - T_z\overline{AD} = 0$

$2400B_x + 40(9.81)0.5(600) - \frac{277}{2\sqrt{2}}(1200) = 0$

$B_x = 0$

$B = B_y = \underline{169.9\ N}$ ($B_x = 0$ can be obtained by inspection by noting $\Sigma M_{AE} = 0$ eliminates all terms except $B_x\overline{BE}$ so $B_x = 0$)

►3/96



$\overline{OA} = 9\ m$, $\overline{OB} = 11\ m$, $\overline{OC} = 13\ m$
$\overline{OD} = 8\ m$, $\overline{OE} = 10\ m$

$\underline{T}_1 = 950[-\sin 30°\cos 10°\,\underline{i} + \cos 30°\cos 10°\,\underline{j} - \sin 10°\,\underline{k}]$

$\underline{T}_2 = 950[-\cos 10°\,\underline{j} - \sin 10°\,\underline{k}]$ (in N)

$\underline{T}_{BE} = T\left[\frac{10\cos 15°\,\underline{i} + 10\sin 15°\,\underline{j} - 11\underline{k}}{\sqrt{221}}\right]$

$\underline{T}_{AD} = T\left[\frac{8\cos 15°\,\underline{i} + 8\sin 15°\,\underline{j} - 9\underline{k}}{\sqrt{145}}\right]$

$\Sigma \underline{M}_O = \underline{0}:\ \underline{r}_{OC} \times (\underline{T}_1 + \underline{T}_2) + \underline{r}_{OB} \times \underline{T}_{BE} + \underline{r}_{OA} \times \underline{T}_{AD} = \underline{0}$

Set $\underline{r}_{OC} = 13\underline{k}\ m$, $\underline{r}_{OB} = 11\underline{k}\ m$, & $\underline{r}_{OA} = 9\underline{k}\ m$, carry out cross products, and set either the $\underline{i}$-component or the $\underline{j}$-component to zero to obtain $\underline{T = 471\ N}$.

$\Sigma F_x = 0:\ -950\sin 30°\cos 10° + 471\frac{10\cos 15°}{\sqrt{221}} + 471\frac{8\cos 15°}{\sqrt{145}} + O_x = 0$

$O_x = -140.0\ N$

$\Sigma F_y = 0:\ 950\cos 30°\cos 10° - 950\cos 10° + 471\frac{10\sin 15°}{\sqrt{221}} + 471\frac{8\sin 15°}{\sqrt{145}} + O_y = 0$

$O_y = -37.5\ N$

Then $O = \sqrt{O_x^2 + O_y^2} = \underline{144.9\ N}$

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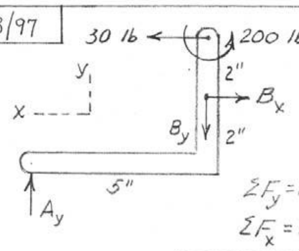


$\Sigma M_B = 0;$

$200 + 30(2) - 5A_y = 0$

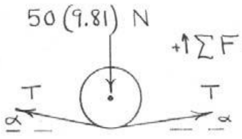
$A_y = 52\ lb$

$\Sigma F_y = 0;\ B_y = 52\ lb$

$\Sigma F_x = 0;\ B_x = 30\ lb$

$B = \sqrt{(30)^2 + (52)^2} = \underline{60.0\ lb}$

3/98 Isolate wheel of unicycle:



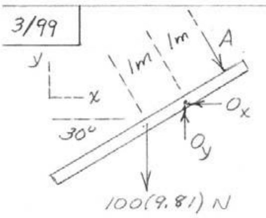
$\alpha = \tan^{-1}\left(\frac{0.075}{9}\right) = 0.477°$

$+\uparrow\Sigma F = 0:\ 2T\sin\alpha - 50(9.81) = 0$

$T = 29\,400\ N$

or $\underline{T = 29.4\ kN}$

3/99



$\Sigma M_O = 0;\ A(1) - (981\cos 30°)1 = 0$

$A = 850\ N$

$\Sigma F_x = 0;\ O_x - 850\sin 30° = 0$

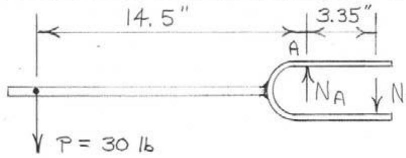
$O_x = 425\ N$

$\Sigma F_y = 0;\ O_y - 850\cos 30° - 981 = 0$

$O_y = 1717\ N$

$O = \sqrt{425^2 + 1717^2} = \underline{1769\ N}$

3/100



$\circlearrowleft \Sigma M_A = 0: \quad 30(14.5) - N_B(3.35) = 0$

$N_B = 129.9$ lb

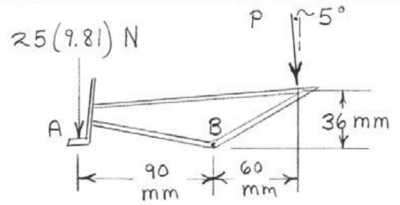
$\uparrow + \Sigma F = 0: \quad -30 + N_A - 129.9 = 0$

$N_A = 159.9$ lb

So the forces applied to the stud are

$\begin{cases} N_A = 159.9 \text{ lb} \downarrow \\ N_B = 129.9 \text{ lb} \uparrow \end{cases}$

3/101



$\circlearrowleft \Sigma M_B = 0: \quad 25(9.81)(90) - P\cos 5°(60) - P\sin 5°(36) = 0$

$P = 351$ N

Assumptions: The weight of the panel acts at the 90-mm dimension as shown above; panel does not slip.

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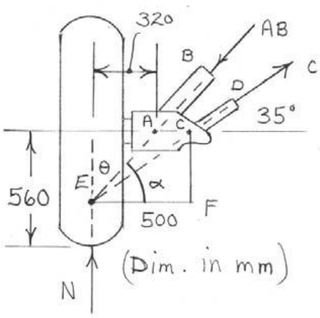

The three forces must be concurrent at point E.

$\overline{CF} = 500 \tan 35° = 350$ mm

$\tan\theta = \dfrac{320}{350}$

$\theta = 42.4°$

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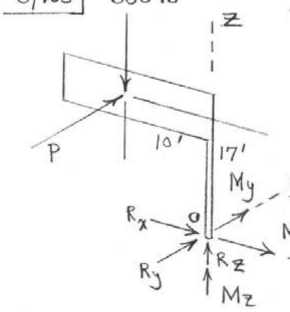


Wind force $P = pA$

$= 17.5(6)(12) = 1260$ lb

$\Sigma F_x = 0 \Rightarrow R_x = 0$

$\Sigma F_y = 0 \Rightarrow R_y = -1260$ lb

$\Sigma F_z = 0 \Rightarrow R_z = 600$ lb

$R = \sqrt{R_x^2 + R_y^2 + R_z^2}$

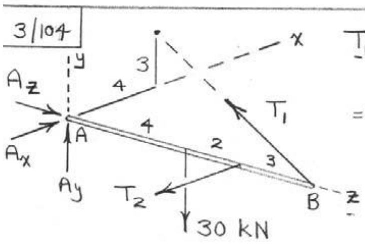
$= 1396$ lb

$\Sigma \underline{M}_O = \underline{0}: \quad \underline{M} + (-10\underline{i} + 17\underline{k}) \times (1260\underline{j} - 600\underline{k}) = \underline{0}$

$\Rightarrow \underline{M} = 21{,}400\,\underline{i} + 6000\,\underline{j} + 12{,}600\,\underline{k}$ lb-ft

$M = 25{,}600$ lb-ft

3/104



$\underline{T}_1 = T_1\left[\dfrac{4\underline{i} + 3\underline{j} - 9\underline{k}}{\sqrt{4^2 + 3^2 + 9^2}}\right]$

$= T_1(0.389\underline{i} + 0.291\underline{j} - 0.874\underline{k})$

$\underline{T}_2 = -T_2\,\underline{i}$

$\Sigma M_x = 0: \quad 30(4) - 0.291\,T_1(9) = 0, \quad T_1 = 45.8$ kN

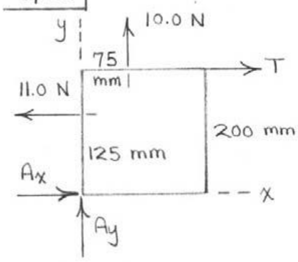
$\Sigma M_y = 0: \quad -T_2(6) + 0.389\,T_1(9) = 0, \quad T_2 = 26.7$ kN

$\Sigma \underline{F} = \underline{0}: \quad \underline{A} + 45.8(0.389\underline{i} + 0.291\underline{j} - 0.874\underline{k}) - 26.7\underline{i} - 30\underline{j} = 0$

$\underline{A} = 8.89\underline{i} + 16.67\underline{j} + 40.0\underline{k}$ kN

$A = 44.2$ kN

3/105

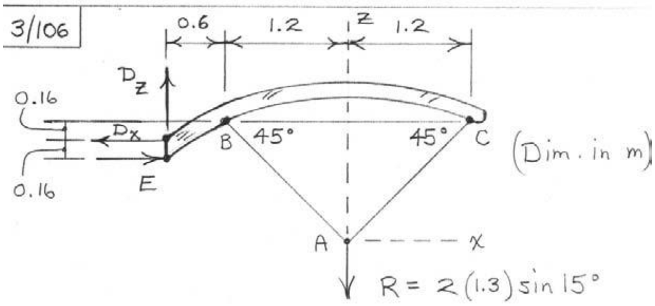


Isolate entire system of plate, pulleys, & tape.

$\circlearrowleft \Sigma M_A = 0: \quad T(200) - 10.0(75) - 11.0(125) = 0$

$T = 10.62$ N

3/106



$R = 2(1.3)\sin 15° = 0.673$ kN

$\Sigma F_z = 0: \; D_z - 0.673 = 0, \quad D_z = 0.673$ kN

$\Sigma M_E = 0: \; 0.16 D_x - 0.673(1.8) = 0$

$D_x = 7.57$ kN

$D = \sqrt{0.673^2 + 7.57^2} = \underline{7.60 \text{ kN}}$

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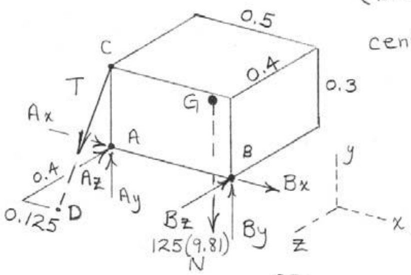
(Dim. in m, G is centered in body)



$\underline{T} = T\, \underline{n}_{CD} = T \dfrac{\underline{CD}}{CD}$

$= T\left[\dfrac{0.125\,\underline{i} - 0.3\,\underline{j} + 0.4\,\underline{k}}{\sqrt{0.125^2 + 0.3^2 + 0.4^2}}\right]$

$= T\,(0.243\,\underline{i} - 0.582\,\underline{j} + 0.776\,\underline{k})$

$\Sigma M_{A_x} = 0: \; 0.776T(0.3) - 125(9.81)(0.2) = 0$

$\underline{T = 1053 \text{ N}}$

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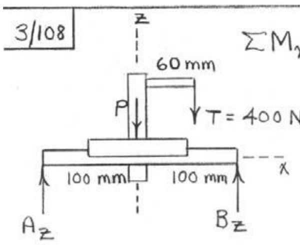

$\Sigma M_x = 0: \; P(200) - 400(120\cos 30°) = 0$

$P = 208$ N

$\Sigma M_{A_y} = 0: \; 208(100) + 400(160) - B_z(200) = 0$

$B_z = 424$ N

$\Sigma F_z = 0: \; A_z + 424 - 208 - 400 = 0, \quad A_z = 183.9$ N

Because $A_y = B_y = 0$, $\underline{A = A_z = 183.9 \text{ N}}$, $\underline{B = B_z = 424 \text{ N}}$

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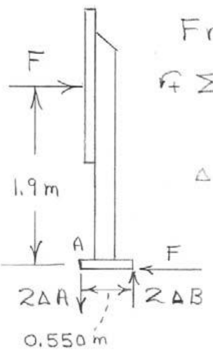


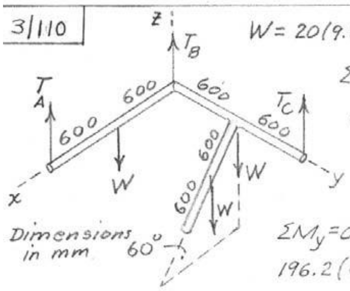
$F = pA = 175(1.6 \cdot 3) = 840$ N

From $\Sigma F = 0, \quad \Delta A = \Delta B$

$\Sigma M_A = 0: \; -840(1.9) + 2\Delta B(0.550) = 0$

$\Delta B = \Delta A = \underline{1451 \text{ N}}$

3/110



$W = 20(9.81) = 196.2$ N

$\Sigma M_x = 0;$

$1200\,T_C - 2(196.2)600 = 0$

$\underline{T_C = 196.2 \text{ N}}$

$\Sigma M_y = 0;$

$196.2(600 + 600\cos 60°) - 1200\,T_A = 0$

$\underline{T_A = 147.2 \text{ N}}$

$\Sigma F_z = 0; \; T_B + 147.2 + 196.2 - 3(196.2) = 0, \quad \underline{T_B = 245 \text{ N}}$

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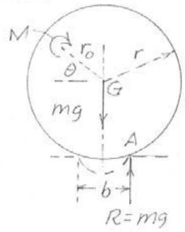

$\Sigma M_A = 0; \; M - mg\dfrac{b}{2} = 0$

$\underline{M = \tfrac{1}{2} mgb}$

$\underline{\text{independent of } r_o, r, \& \theta}$

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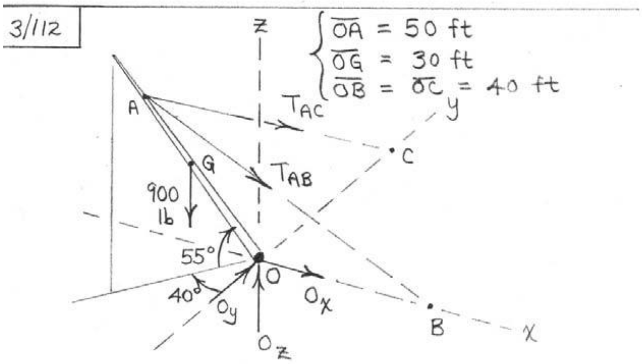

Coordinates of A: $50(-\cos 55°\sin 40°, -\cos 55°\cos 40°, \sin 55°) = (-18.43, -22.0, 41.0)$ ft

Coordinates of G: $30(-\cos 55°\sin 40°, -\cos 55°\cos 40°, \sin 55°) = (-11.06, -13.18, 24.6)$ ft

$$\underline{T}_{AB} = T_{AB}\left[\frac{(18.43+40)\underline{i} + 22.0\underline{j} - 41.0\underline{k}}{\sqrt{(18.43+40)^2 + 22.0^2 + 41.0^2}}\right]$$

$$= T_{AB}\left[0.783\underline{i} + 0.294\underline{j} - 0.549\underline{k}\right]$$

$$T_{AC} = T_{AC}\left[\frac{18.43\underline{i} + (22.0+40)\underline{j} - 41.0\underline{k}}{\sqrt{18.43^2 + (22.0+40)^2 + 41.0^2}}\right]$$

$$= T_{AC}\left[0.241\underline{i} + 0.810\underline{j} - 0.535\underline{k}\right]$$

$\Sigma F_x = 0: \quad 0.783 T_{AB} + 0.241 T_{AC} + O_x = 0 \qquad (1)$

$\Sigma F_y = 0: \quad 0.294 T_{AB} + 0.810 T_{AC} + O_y = 0 \qquad (2)$

$\Sigma F_z = 0: \quad -0.549 T_{AB} - 0.535 T_{AC} + O_z - 900 = 0 \qquad (3)$

$\Sigma M_{BC} = 0: \quad \Sigma \underline{M}_B \cdot \underline{n}_{BC} = 0:$

$$\left\{-40\underline{i} \times O_z\underline{k} + \left[(-40-11.06)\underline{i} - 13.18\underline{j}\right] \times \left[-900\underline{k}\right]\right\} \cdot \left(-\frac{\sqrt{2}}{2}\underline{i} + \frac{\sqrt{2}}{2}\underline{j}\right) = 0$$

or $\left(40 O_z - 46{,}000\right)\frac{\sqrt{2}}{2} - 11{,}860\,\frac{\sqrt{2}}{2} = 0 \qquad (4)$

$\Sigma M_{O_y} = 0: \quad 0.549\, T_{AB}(40) - 900(11.06) = 0 \qquad (5)$

Solve Eqs. (1)-(5) in reverse order to obtain

$$\begin{cases} O_x = -489 \text{ lb} & T_{AB} = 454 \text{ lb} \\ O_y = -582 \text{ lb} & T_{AC} = 554 \text{ lb} \\ O_z = 1445 \text{ lb} & \end{cases}$$

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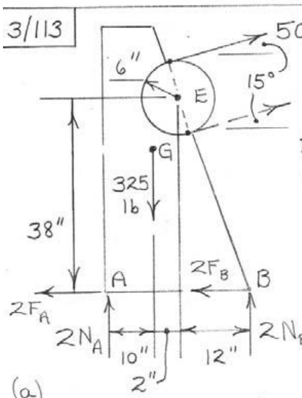

Because of symmetry, $N_A = N_D$ & $N_B = N_C$.

For (a), replace 50-lb force by a 50-lb force & 300 lb-in. CW couple at E (CCW for (b)).

(a)

$\circlearrowleft + \Sigma M_A = 0: \; -325(10) + 2N_B(24) - 50\cos 15°(38) + 50\sin 15°(12) - 300 = 0, \; \underline{N_B = N_C = 109.0 \text{ lb}}$

$+\uparrow \Sigma F = 0: \; 2(109.0) + 2N_A - 325 + 50\sin 15° = 0$

$\underline{N_A = N_D = 47.1 \text{ lb}}$

(b) Reverse the sign on the 300 lb-in. couple & obtain

$$\begin{cases} N_B = N_C = 96.5 \text{ lb} \\ \underline{N_A = N_D = 59.6 \text{ lb}} \end{cases}$$

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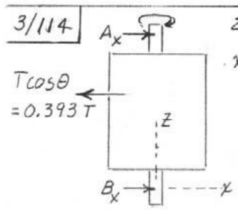


$\Sigma M_z = 0; \; 120 - 0.150T = 0, \; T = 800$ N

x-z; $\Sigma M_B = 0; \; 0.393(800)(0.360) - 0.700A_x = 0; \; A_x = 161.6$ N

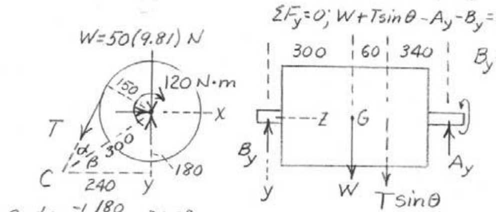
$\Sigma F_x = 0; \; B_x + 161.6 - 0.393(800) = 0$

$B_x = 152.6$ N

y-z; $\Sigma M_B = 0; \; 0.7A_y - 0.920(800)(0.360) - 50(9.81)(0.300) = 0; \; A_y = 588.6$ N

$\Sigma F_y = 0; \; W + T\sin\theta - A_y - B_y = 0,$

$B_y = 637.6$ N



$\beta = \tan^{-1}\frac{180}{240} = 36.9°$

$\alpha = \sin^{-1}\frac{150}{300} = 30°$

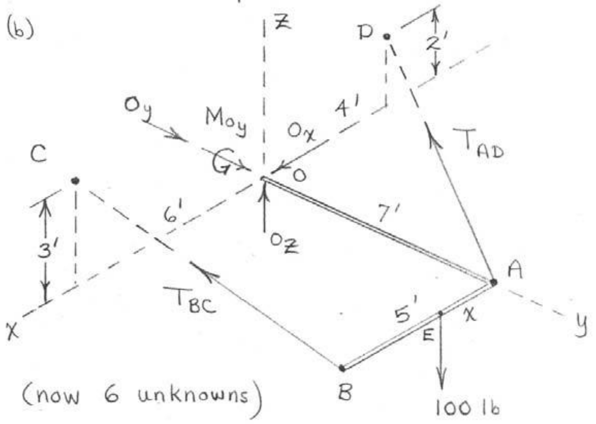
$\theta = \alpha + \beta = 66.9°$

$A = \sqrt{(161.6)^2 + (588.6)^2} = \underline{610 \text{ N}}$

$B = \sqrt{(152.6)^2 + (637.6)^2} = \underline{656 \text{ N}}$

▸3/115 (a) There are 5 unknown constraint forces. The bar is free to rotate about a line which passes through point O and through which the lines of action of both tension forces pass.

(b)



(now 6 unknowns)

$$\mathbf{T}_{AD} = T_{AD}\left[\frac{-4\mathbf{i} - 7\mathbf{j} + 2\mathbf{k}}{\sqrt{69}}\right]$$

$$\mathbf{T}_{BC} = T_{BC}\left[\frac{\mathbf{i} - 7\mathbf{j} + 3\mathbf{k}}{\sqrt{59}}\right]$$

$$\Sigma F_x = 0: \quad O_x - \frac{4}{\sqrt{69}}T_{AD} + \frac{1}{\sqrt{59}}T_{BC} = 0 \qquad (1)$$

$$\Sigma F_y = 0: \quad O_y - \frac{7}{\sqrt{69}}T_{AD} - \frac{7}{\sqrt{59}}T_{BC} = 0 \qquad (2)$$

$$\Sigma F_z = 0: \quad O_z + \frac{2}{\sqrt{69}}T_{AD} + \frac{3}{\sqrt{59}}T_{BC} - 100 = 0 \qquad (3)$$

$$\Sigma M_{O_x} = 0: \quad 7\left(\frac{2}{\sqrt{69}}T_{AD}\right) + 7\left(\frac{3}{\sqrt{59}}T_{BC}\right) - 7(100) = 0 \qquad (4)$$

$$\Sigma M_{O_y} = 0: \quad -5\left(\frac{3}{\sqrt{59}}T_{BC}\right) + M_{O_y} + 100x = 0 \qquad (5)$$

$$\Sigma M_{O_z} = 0: \quad 7\left(\frac{4}{\sqrt{69}}T_{AD}\right) - 7\left(\frac{1}{\sqrt{59}}T_{BC}\right) - 5\left(\frac{7}{\sqrt{59}}T_{BC}\right) = 0 \qquad (6)$$

Solve Eqs. (1)-(6) over $0.5 \le x \le 4.5$ ft and discover that three of the requested quantities are constant:

$$\begin{cases} O_x = 83.3 \text{ lb} \\ O_y = 292 \text{ lb} \\ O_z = 0 \end{cases}$$

$T_{AD} = 208$ lb = constant

$T_{BC} = 128.0$ lb = constant

$O = \sqrt{O_x^2 + O_y^2 + O_z^2} = 303$ lb = constant

and $M_{O_y} = -100x + 250$ (in lb-ft if x in ft)

(Note that O_y could have been obtained from $\Sigma M_{CD} = 0$ & O_z from $\Sigma M_{AB} = 0$)

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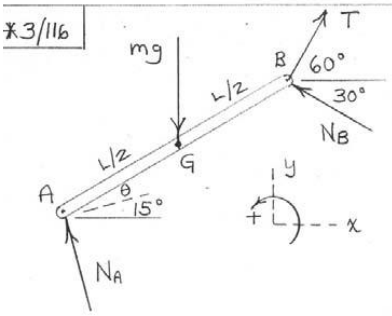
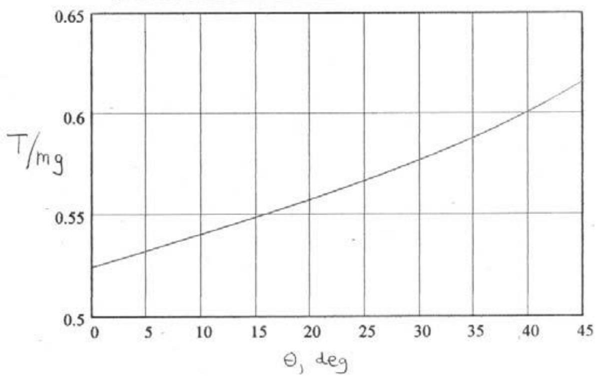


$$\Sigma F_x = 0: -N_A \sin 15° - N_B \cos 30° + T \sin 30° = 0$$

$$\Sigma F_y = 0: \quad N_A \cos 15° + N_B \sin 30° + T\cos 30° - mg = 0$$

$$\Sigma M_B = 0: \quad mg\frac{L}{2}\cos(\theta + 15°) - N_A \cos\theta\,(L) = 0$$

Solving, $T = mg\,\dfrac{\frac{\sqrt{3}}{2}\cos\theta - \frac{\sqrt{2}}{4}\cos(\theta + 15°)}{\cos\theta}$



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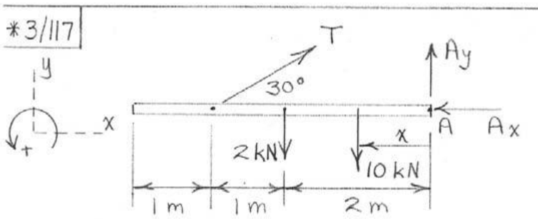


(Weight of beam = 200(10)/1000 = 2 kN)

$$\Sigma M_A = 0: \quad 10x + 2(2) - T\sin 30°(3) = 0$$

$$T = \frac{2}{3}(10x + 4) \quad \text{(in kN)}$$

$$\Sigma F_x = 0: \quad T\cos 30° - A_x = 0$$

$$A_x = \frac{1}{\sqrt{3}}(10x + 4)$$

$$\Sigma F_y = 0: \quad T\sin 30° - 2 - 10 + A_y = 0$$

$$A_y = \frac{1}{3}(-10x + 32)$$

$$R = \left\{A_x^2 + A_y^2\right\}^{1/2} = \frac{1}{3}\left\{400x^2 - 400x + 1072\right\}^{1/2}$$

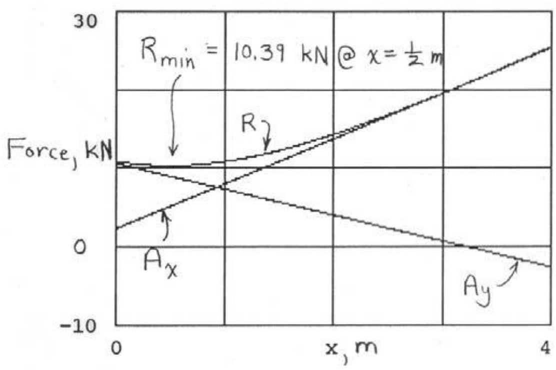
Set $\dfrac{dR^2}{dx} = 0$: $\quad 800x - 400 = 0$

$$x = \frac{1}{2} \text{ m}$$

$$R_{min} = \frac{1}{3}\left\{400\left(\frac{1}{2}\right)^2 - 400\left(\frac{1}{2}\right) + 1072\right\}^{1/2}$$

$= 10.39$ kN (b)

Plot of A_x, A_y, and R:



(a)

(c)

$R_{max} = 24.3$ kN @ $x = 3.8$ m is the value of R which must be used for the design of the pin at A.

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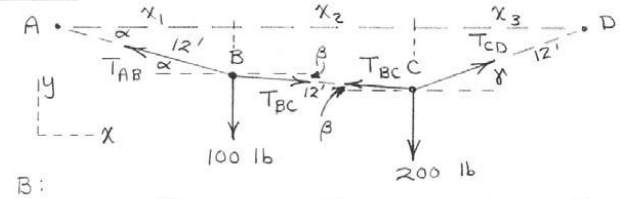

B:

$\Sigma F_x = 0: \; -T_{AB}\cos\alpha + T_{BC}\cos\beta = 0$ (1)

$\Sigma F_y = 0: \; T_{AB}\sin\alpha - T_{BC}\sin\beta - 100 = 0$ (2)

C:

$\Sigma F_x = 0: \; -T_{BC}\cos\beta + T_{CD}\cos\gamma = 0$ (3)

$\Sigma F_y = 0: \; T_{BC}\sin\beta + T_{CD}\sin\gamma - 200 = 0$ (4)

$\cos\alpha = \frac{x_1}{12}, \quad \cos\beta = \frac{x_2}{12}, \quad \cos\gamma = \frac{x_3}{12}$

So $12\cos\alpha + 12\cos\beta + 12\cos\gamma = 35$ (5)

$\sin\alpha + \sin\beta = \sin\gamma$ (from figure)(6)

Solve numerically:

$\alpha = 14.44°$ $\quad T_{AB} = 529$ lb
$\beta = 3.57°$ $\quad T_{BC} = 513$ lb
$\gamma = 18.16°$ $\quad T_{CD} = 539$ lb

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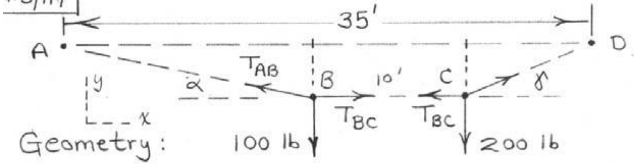

Geometry:

$\overline{AB} + \overline{BC} + \overline{CD} = 36$ ft (1)

$\overline{AB}\cos\alpha + \overline{BC} + \overline{CD}\cos\gamma = 35$ ft (2)

$\overline{AB}\sin\alpha = \overline{CD}\sin\gamma$ (3)

Equilibrium:

B $\begin{cases} \Sigma F_x = 0: \; -T_{AB}\cos\alpha + T_{BC} = 0 & (4) \\ \Sigma F_y = 0: \; T_{AB}\sin\alpha - 100 = 0 & (5) \end{cases}$

C $\begin{cases} \Sigma F_x = 0: \; -T_{BC} + T_{CD}\cos\gamma = 0 & (6) \\ \Sigma F_y = 0: \; T_{CD}\sin\gamma - 200 = 0 & (7) \end{cases}$

With $\overline{BC}$ set to 10 ft, solve 7 equations in 7 unknowns & obtain

$\overline{AB} = 17.01$ ft | $\alpha = 11.47°$ | $T_{AB} = 503$ lb
$\overline{CD} = 8.99$ ft | $\gamma = 22.1°$ | $T_{BC} = 493$ lb
$T_{CD} = 532$ lb

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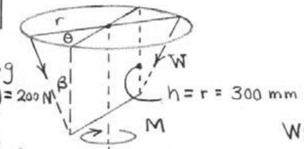
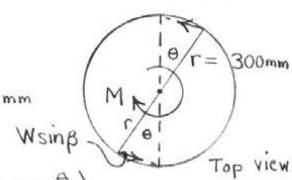


$W = mg$
$= 20(10) = 200$ N

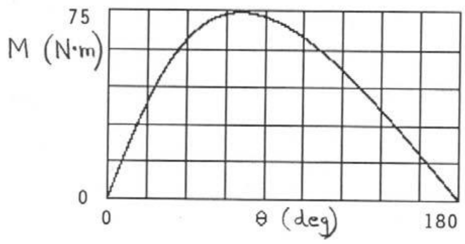


Top view,

$\Sigma M = 0: \quad M = 2W\sin\beta\left(r\cos\frac{\theta}{2}\right)$

where $\sin\beta = 2r\sin\frac{\theta}{2} \Big/ \sqrt{\left(2r\sin\frac{\theta}{2}\right)^2 + h^2}$

With $h = r$: $M = 2Wr\dfrac{\sin\theta}{\sqrt{4\sin^2\frac{\theta}{2} + 1}} = 120\dfrac{\sin\theta}{\sqrt{4\sin^2\frac{\theta}{2}+1}}$ N·m



$M_{max} = 74.2$ N·m @ $\theta = 67.5°$

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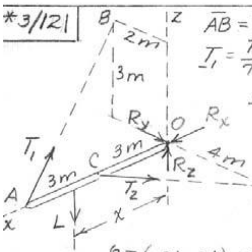


$\overline{AB} = \sqrt{6^2 + 2^2 + 3^2} = 7$ m, $\overline{CD} = \sqrt{3^2 + 4^2} = 5$ m

$\underline{T}_1 = \frac{T_1}{7}(-6\underline{i} - 2\underline{j} + 3\underline{k})$, $\underline{T}_2 = \frac{T_2}{5}(-3\underline{i} + 4\underline{j})$, $\underline{L} = -L\underline{k}$

$\underline{r}_1 = 6\underline{i}$, $\underline{r}_2 = 3\underline{i}$, $\underline{r} = x\underline{i}$

$\Sigma \underline{M}_O = \underline{0}: \; \underline{r}_1 \times \underline{T}_1 + \underline{r}_2 \times \underline{T}_2 + \underline{r} \times \underline{L} = \underline{0}$

$6\underline{i} \times \frac{T_1}{7}(-6\underline{i} - 2\underline{j} + 3\underline{k})$
$+ 3\underline{i} \times \frac{T_2}{5}(-3\underline{i} + 4\underline{j}) + x\underline{i} \times (-L\underline{k}) = 0$

Expand: $\frac{6}{7}T_1(-2\underline{k} - 3\underline{j}) + \frac{3}{5}T_2(4\underline{k}) + Lx\underline{j} = \underline{0}$

$-\frac{12}{7}T_1 + \frac{12}{5}T_2 = 0, \quad -\frac{18}{7}T_1 + Lx = 0$, so $T_1 = \frac{7}{18}Lx$, $T_2 = \frac{5}{18}Lx$

$\Sigma F_x = 0$; $R_x - \frac{3}{5}T_2 - \frac{6}{7}T_1 = 0$, $R_x = \frac{3}{5}\frac{5}{18}Lx + \frac{6}{7}\frac{7}{18}Lx = \frac{1}{2}Lx$

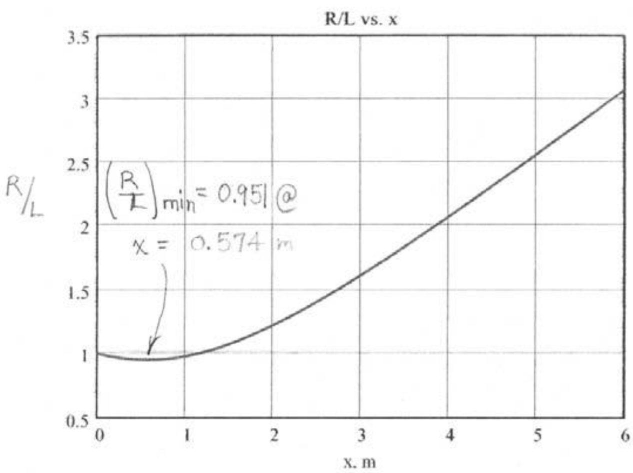
$\Sigma F_y = 0$; $R_y + \frac{4}{5}T_2 - \frac{2}{7}T_1 = 0$, $R_y = -\frac{4}{5}\frac{5}{18}Lx + \frac{2}{7}\frac{7}{18}Lx = -\frac{1}{9}Lx$

$\Sigma F_z = 0$; $R_z - L + \frac{3}{7}T_1 = 0$, $R_z = L - \frac{3}{7}\frac{7}{18}Lx = L(1 - \frac{1}{6}x)$

$R^2 = L^2\left(\frac{x^2}{4} + \frac{x^2}{81} + 1 - \frac{x}{3} + \frac{x^2}{36}\right)$

$R/L = \sqrt{(47x^2/162) - x/3 + 1}$

$\frac{dR^2/L^2}{dx} = \frac{47x}{81} - \frac{1}{3} = 0$ for min.; $x = 0.574$ m



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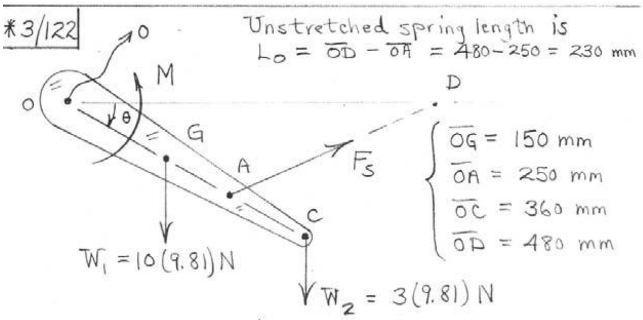
Unstretched spring length is $L_0 = \overline{OD} - \overline{OA} = 480 - 250 = 230$ mm



$\overline{OG} = 150$ mm, $\overline{OA} = 250$ mm, $\overline{OC} = 360$ mm, $\overline{OD} = 480$ mm

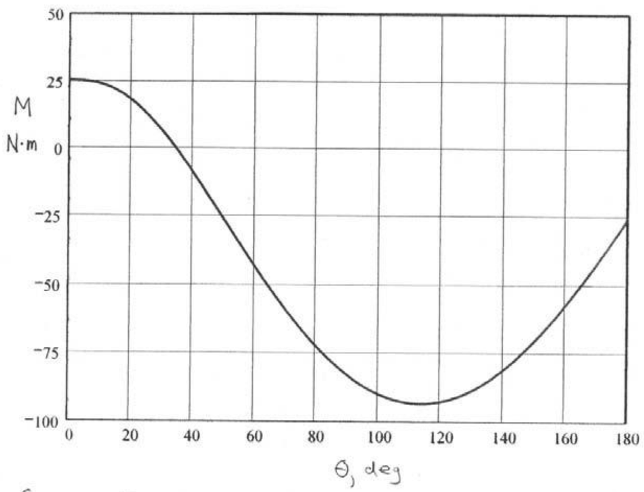
$\underline{AD} = (\overline{OD} - \overline{OA}\cos\theta)\underline{i} + \overline{OA}\sin\theta\,\underline{j}$

$\overline{AD} = \left\{\left[\overline{OD} - \overline{OA}\cos\theta\right]^2 + \left[\overline{OA}\sin\theta\right]^2\right\}^{1/2}$

$\underline{F_s} = k(\overline{AD} - L_0)\dfrac{\underline{AD}}{\overline{AD}}$; $\underline{r}_{OA} = \overline{OA}(\cos\theta\underline{i} - \sin\theta\underline{j})$

$\Sigma M_O = 0$: $M - (W_1\overline{OG} + W_2\overline{OC})\cos\theta + (\underline{r}_{OA} \times \underline{F_s})_z = 0$

Carry out algebra, solve for M as a function of θ, & plot to obtain

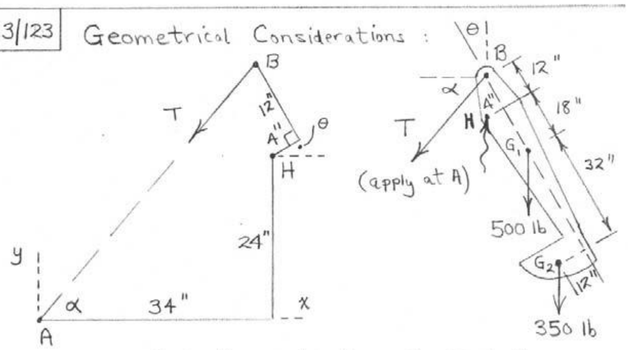


$M = 0$ @ $\theta = 34.6°$

$M_{min} = -93.4$ N·m @ $\theta = 113.9°$

$M_{max} = 25.3$ N·m @ $\theta = 0$

*3/123 Geometrical Considerations :



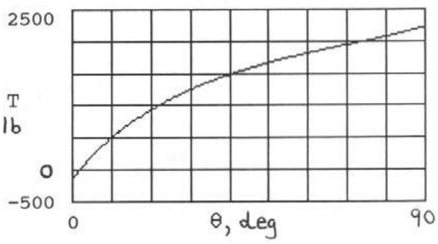
Coordinates of B : $\begin{cases} x = 34 + 4\cos\theta - 12\sin\theta \\ y = 24 + 4\sin\theta + 12\cos\theta \end{cases}$ (in.) (1)

$\therefore\ \alpha = \tan^{-1}\dfrac{y}{x}$ (aims $\underline{T}$) (2)

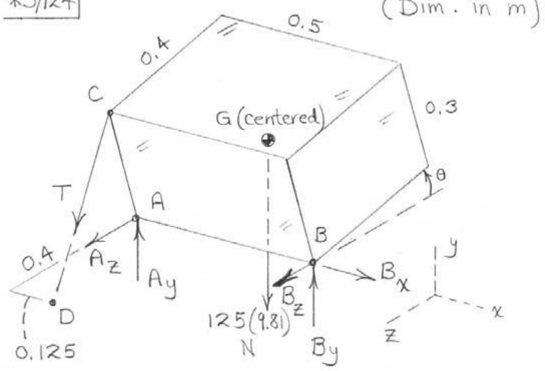
$\circlearrowleft \Sigma M_H = 0$: $-(T\cos\alpha)(24) + (T\sin\alpha)(34) - 500(18\sin\theta + 4\cos\theta) - 350(4\cos\theta + (18+32)\sin\theta - 12\cos\theta) = 0$

$\Rightarrow T = \dfrac{26{,}500\sin\theta - 800\cos\theta}{34\sin\alpha - 24\cos\alpha}$ (lb; positive is tension in AB)

Solve (1), (2), & (3) & plot : (Note T=0 @ θ = 1.729°)



*3/124 (Dim. in m)



$\underline{CD} = 0.125\underline{i} - 0.3\cos\theta\,\underline{j} + (0.4 - 0.3\sin\theta)\underline{k}$

Then $\underline{T} = T\underline{n}_{CD} = T\dfrac{\underline{CD}}{\overline{CD}}$, or

$\underline{T} = T\left[\dfrac{0.125\underline{i} - 0.3\cos\theta\underline{j} + (0.4 - 0.3\sin\theta)\underline{k}}{\sqrt{0.266 - 0.24\sin\theta}}\right]$

$\Sigma F_x = 0$: $\dfrac{0.125T}{\sqrt{0.266 - 0.24\sin\theta}} + B_x = 0$ (1)

$\Sigma F_y = 0$: $\dfrac{-0.3T\cos\theta}{\sqrt{0.266 - 0.24\sin\theta}} + A_y + B_y - 125(9.81) = 0$ (2)

$$\Sigma F_z = 0: \quad \frac{(0.4 - 0.3\sin\theta)\,T}{\sqrt{0.266 - 0.24\sin\theta}} + A_z + B_z = 0 \qquad (3)$$

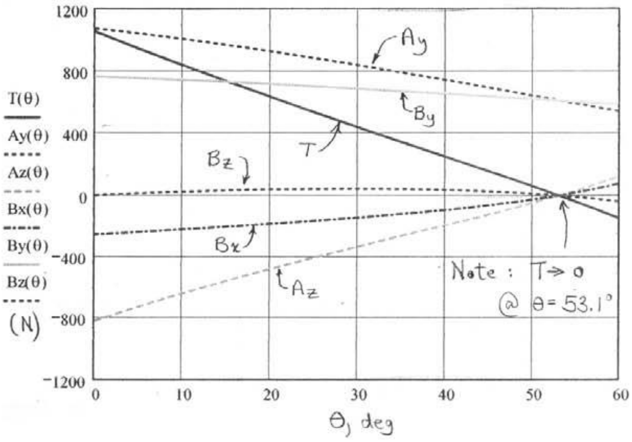
$$\Sigma M_{D_x} = 0: \quad (A_y + B_y)(0.4) - 125(9.81)(0.4 + 0.2\cos\theta - 0.15\sin\theta) = 0 \qquad (4)$$

$$\Sigma M_{D_y} = 0: \quad -B_x(0.4) + A_z(0.125) - B_z(0.375) = 0 \qquad (5)$$

$$\Sigma M_{D_z} = 0: \quad -A_y(0.125) + B_y(0.375) - 125(9.81)(0.125) = 0 \qquad (6)$$

Computer Solution:

$$\begin{cases} T = -12.77\,\dfrac{-4\cos\theta + 3\sin\theta}{\cos\theta}\sqrt{425 - 384\sin\theta} \\ A_y = 613 + 460\cos\theta - 345\sin\theta \\ A_z = -12.77\,\dfrac{64\cos\theta - 48\sin\theta - 36\sin\theta\cos\theta + 27\cos^2\theta}{\cos\theta} \\ B_x = 63.9\,\dfrac{-4\cos\theta + 3\sin\theta}{\cos\theta} \\ B_y = 613 + 153.3\cos\theta - 115.0\sin\theta \\ B_z = -38.3\,\dfrac{-4\cos\theta + 3\sin\theta}{\cos\theta}\sin\theta \end{cases}$$



*3/125 With reference to the FBD and solution to Prob. 3/96, the various tension vectors are

$$\underline{T}_2 = 1000\,(0\,\underline{i} - \cos 10°\,\underline{j} - \sin 10°\,\underline{k})\ \text{N}$$

$$\underline{T}_1 = T_1\,(-\sin 30°\cos 10°\,\underline{i} + \cos 30°\cos 10°\,\underline{j} - \sin 10°\,\underline{k})$$

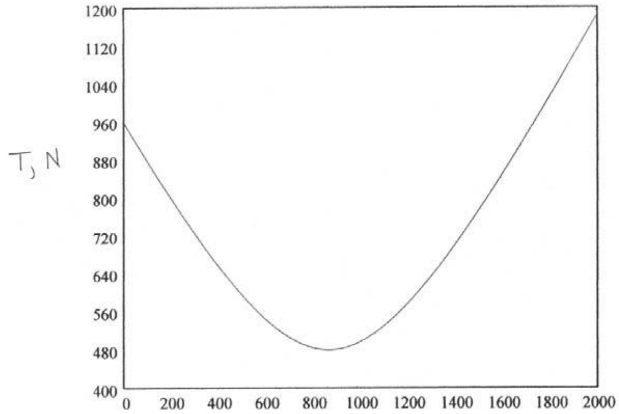
$$\underline{T}_{BE} = \frac{T\,(10\cos\theta\,\underline{i} + 10\sin\theta\,\underline{j} - 11\underline{k})}{\sqrt{(10\cos\theta)^2 + (10\sin\theta)^2 + 11^2}}$$

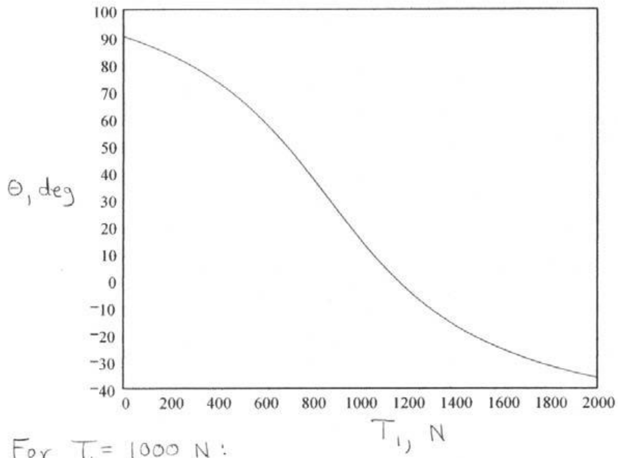
$$\underline{T}_{AD} = \frac{T\,(8\cos\theta\,\underline{i} + 8\sin\theta\,\underline{j} - 9\underline{k})}{\sqrt{(8\cos\theta)^2 + (8\sin\theta)^2 + 9^2}}$$

Needed position vectors are $\underline{r}_{OC} = 13\underline{k}$ m, $\underline{r}_{OB} = 11\underline{k}$ m, & $\underline{r}_{OA} = 9\underline{k}$ m.

$$\Sigma \underline{M}_O = \underline{0}: \quad \underline{r}_{OC} \times (\underline{T}_1 + \underline{T}_2) + \underline{r}_{OB} \times \underline{T}_{BE} + \underline{r}_{OA} \times \underline{T}_{AD} = \underline{0}$$

Carry out cross products, collect terms, & set the $\underline{i}$- & $\underline{j}$-components to zero, solving for T and θ for each value of T_1. Resulting plots:





For $T_1 = 1000$ N:

$T = 495$ N, $\theta = 15°$